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DISTRIBUTION OF THE HUNGARIAN PARTRIDGE IN NEW YORK[1]

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ABSTRACT

Some 27,750 Hungarian partridges were stocked in New York State during the period from 1927 to 1932. The birds disappeared in most localities soon after release, although colonies persisted in a few places. Along the St. Lawrence River in northern New York the birds gradually increased until, in 1952, it was possible to declare an open season.

In order to obtain information concerning the present-day distribution and abundance of these birds questionnaires were mailed to game protectors, and additional data were obtained from district game managers. As a result, it is known that the species occurs in eight counties but is present in appreciable numbers only in Jefferson, St. Lawrence, and Franklin Counties.

Soil types, land use, climatic conditions, and the status of other game species are discussed in relation to the Hungarian partridge population. Primary reasons for success of the birds in the St. Lawrence valley are considered to be the dry weather in late spring and summer, the large proportion of cropland in grain, the presence of suitable cover, light hunting pressure, and lack of competition from pheasants.

The present Hungarian partridge population in New York State stems chiefly from large-scale releases by the Conservation Department during the period from 1927 to 1932. Earlier releases, between 1916 and 1921, apparently had failed. Wells (1951) summarized available information relative to the introduction of the species in this State. He pointed out that, although 27,750 birds were released during the 6-year period ending in 1932, they failed to become established over most of the State.

The comparatively flat land between the Adirondacks and the St. Lawrence River in Jefferson, St. Lawrence, and Franklin Counties proved to be an exception. Here the species has prospered, although there have been major fluctuations in its population level. In fact, the birds multiplied to an extent that open seasons were possible in 1952 and 1953.

The present investigation was undertaken in order to determine

[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project W-81-R.

the current distribution and relative abundance of Hungarian partridges over the State in relation to soil types, land use, climatic conditions, and related factors.

PROCEDURE

Questionnaires were mailed to game protectors in counties where Hungarians were known to be present, and to those in counties where the birds formerly had occurred. Additional information was secured from district game managers and private cooperators. Limited field work was carried out in checking on reports of occurrence in areas of scarcity.

District Game Manager John Wilson furnished copies of his survey reports for 1952 and 1953, covering game protectors' observations in the Ontario-St. Lawrence region. Data from these reports were included with information secured from the questionnaires as a basis for plotting distribution.

FINDINGS

Including all of each township from which the species was reported, the present range in the State is shown in Figure 1.

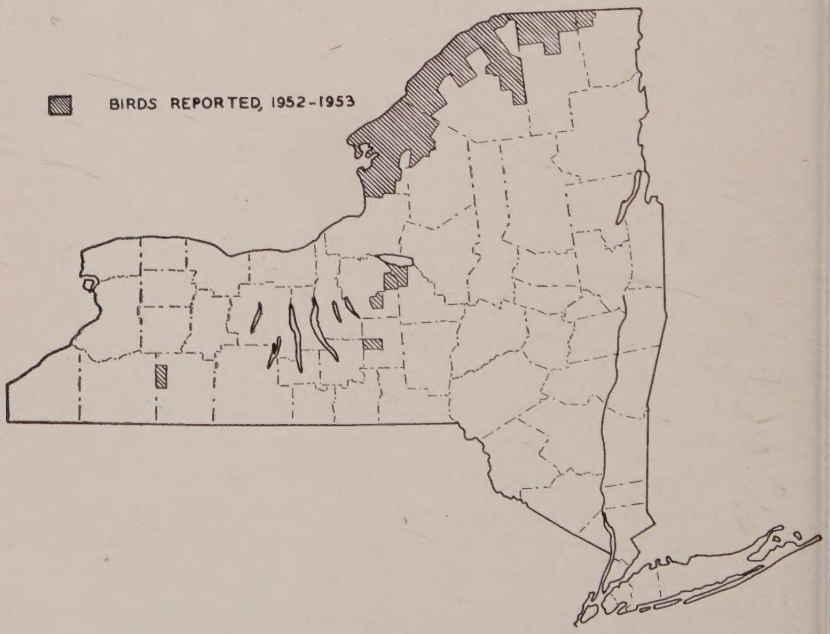

Figure 1. Present range of the Hungarian partridge in New York State, by townships.

Hungarians were reported as having been seen during 1952 and 1953 in every township in Jefferson County, in 17 of the 32 townships in St. Lawrence County (including all those bordering on the St. Lawrence River), in nine of the northernmost townships in Franklin County, and in one township in northern Clinton County. The observations reported covered the winter months, for the most part, and thus pertained to concentrations of coveys. The figures listed in Table 1 refer to the total number of birds seen per month. Because some flocks apparently were reported by more than one cooperator there is no sound basis for calculating the number of birds seen per township.

Elsewhere in the State there are recent records of Hungarian partridges being seen in small numbers in portions of Cortland, Onondaga, Allegany, and Wyoming Counties. These appear to represent local situations where the birds have persisted in small numbers, but have failed to increase.

DISCUSSION

The success of the introduction of Hungarian partridges in the lowlands along the upper St. Lawrence River, as compared with the general failure of the species to persist and increase elsewhere in the State, poses this question: What soil, climatic, or other conditions constitute the deciding factors in the situation?

According to Howe (1935) the soils occurring in the portions of the St. Lawrence valley occupied by the birds include the Vergennes clay, Ontario silt loam, Coloma fine sandy loam, and Gloucester loam. The Vergennes clay is of medium productivity, and occurs also in the Champlain and Hudson lowlands. This soil is derived partly from lacustrine sediments and partly from Ordovician limestones and shales. The surface portions are acid, while the subsoil is calcareous.

The Ontario loam series is represented in this area primarily by the Madrid loam. Occurring in northern Franklin and St. Lawrence Counties, as well as in east-central Jefferson County, this soil is alkaline and highly productive. It is derived from the weathering of glacial till, mostly of limestone origin. Ontario loams occur also in a belt stretching from Erie County to the Hudson River.

The Coloma fine sandy loam occurs in the northern parts of St. Lawrence, Franklin, and Clinton Counties. Derived from Potsdam sandstone of the Cambrian period, this soil is moderately productive but extremely deficient in lime.

The Gloucester loam occurs along the fringe of the Hungarian partridge range farthest from the St. Lawrence River. The Gloucester

TABLE 1. REPORTED OCCURRENCE OF HUNGARIAN PARTRIDGES IN NEW YORK (1952-53)*

County	Township	Birds seen		
		Date		Number
Allegany	New Hudson	November	1952	15
	Rushford	November	1952	25
	Rushford	October	1953	8
Cortland	Cortlandville	October	1952	12
Franklin	Bangor	May	1953	10
	Bombay	?	1953	22
	Fort Covington	December	1952	6
	Fort Covington	February	1953	60
	Malone	June	1953	16
	Moira	?	1953	12
	St. Regis Indian Res.	February-March	1952	100
	St. Regis Indian Res.	December	1952	15
Jefferson	Alexandria	March	1952	62
	Alexandria	January-March	1953	34
	Brownville	January-March	1952	41
	Brownville	January-March	1953	75
	Cape Vincent	February-March	1952	104
	Cape Vincent	January-March	1953	53
	Clayton	February	1952	6
	Clayton	January-March	1953	60
	Ellisburg	December	1952	24
	Lorraine	January	1953	12
	Lyme	February-March	1952	92
	Lyme	January-March	1953	36
	Orleans	?	1952	40
	Orleans	January-March	1953	35
	Pamelia	February	1952	24
	Philadelphia	February	1952	17
	Theresa	February	1952	47
	Wilna	October	1952	40
Madison	Sullivan	Fall	1953	11
Onondaga	Manlius	?	1952	26
	Pompey	Fall	1953	9
St. Lawrence	DePeyster	February	1953	15
	Hammond	March	1952	30
	Hopkinton	February	1953	14
	Lisbon	March	1952	80
	Lisbon	December-February	1952-53	55
	Louisville	March	1952	26
	Macomb	March	1952	15
	Macomb	December	1952	7
	Madrid	February	1952	20
	Morristown	December	1952	28
	Oswegatchie	March	1952	35
	Parishville	February	1952	12
	Waddington	March	1952	40
Wyoming	Perry	November	1953	8

* Although their numbers were not recorded, birds were seen in Clinton County (Clinton Township) and Wyoming County (Gainesville Township) in 1953.

series actually includes several stony and sandy loams of acid reaction and low fertility, formed from the pre-Cambrian metamorphic and igneous rocks which constitute the Adirondack highland. Soils of the Gloucester group are found, also, in portions of Putnam, Westchester, Rensselaer, and Rockland Counties.

Those portions of the St. Lawrence valley where the Hungarians have prospered average between 30 and 45 per cent in cropland. The predominant agricultural pursuit is dairying, with large acreages in pasture and hay. A substantial portion of the tilled land is devoted to grain. Table 2 provides information concerning acreages in the more important crops as recorded by the U. S. Department of Commerce (1950).

TABLE 2. SELECTED LAND USE STATISTICS FOR CERTAIN NORTHERN NEW YORK COUNTIES IN 1949

Item	Jefferson	St. Lawrence	Franklin	Clinton
Total land area (acres)	827,520	1,774,080	1,078,400	677,760
Percentage in farms	70.8	50.0	24.3	59.1
Acreage of cropland harvested	243,249	285,121	108,576	119,214
Acreage of:				
Hay	167,567	225,499	83,634	92,401
Oats (threshed)	35,445	23,456	7,524	4,165
Corn (for grain)	699	596	81	192
Mixed grain	13,080	5,057	2,077	2,068
Wheat (winter and spring)	3,989	786	32	61
Buckwheat	414	717	384	630
Acreage in pasture	265,848	453,788	143,016	195,547
Acreage in woodland	84,291	210,458	73,490	163,617

The census records reveal that dairying likewise is the most important farm enterprise in other parts of the State, including such counties as Otsego, Delaware, Schoharie, and Cortland. However, the proportion of tilled land devoted to the various crops differs considerably in these counties from that in the counties along the northern border. It is interesting to note that the agricultural situation in Oswego County, which borders on Lake Ontario, is not greatly different from that in the counties listed in Table 2. For instance,

Oswego County has about 60 per cent of its cropland in hay as compared with approximately 69 per cent in Jefferson County and, surprisingly enough, Oswego has about 17 per cent of its cropland in grain while Franklin County has but 9 per cent. Despite the apparently favorable food and cover conditions Oswego County has few, if any, Hungarian partridges.

Figure 2, which shows the variation in lime requirement of the soils in the various parts of the State, serves also to depict soil productivity since the areas of low lime requirement coincide, in general, with the areas of high productivity. It is apparent from this map that, in comparison with the upper St. Lawrence valley, there are large areas in New York of equal or higher soil fertility.

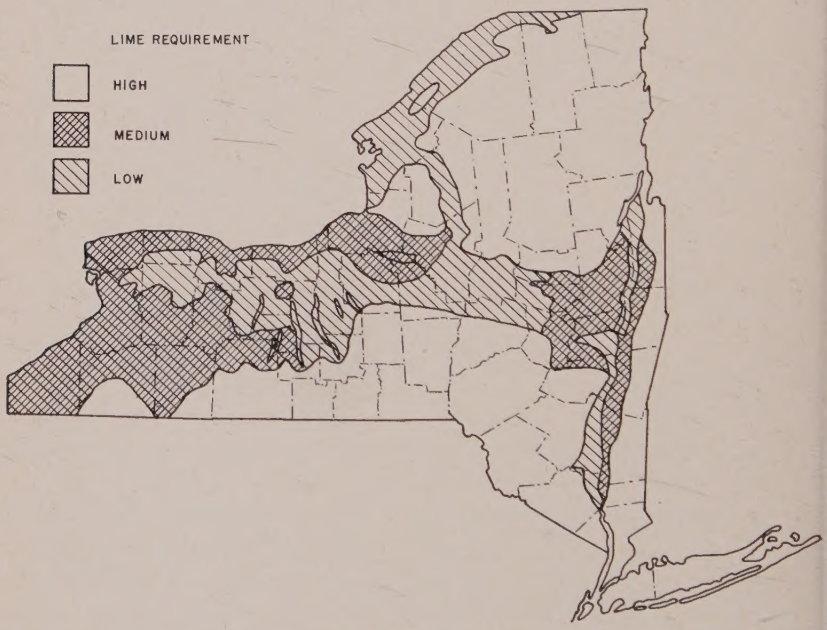

Figure 2. Lime requirement map. (Adapted from N. Y. S. Planning Board, 1935)

The mean annual precipitation in New York's Hungarian partridge range (30 to 40 inches) is much the same as that for the greater part of the State (Figure 3). During the summer months, however, rainfall in the St. Lawrence valley is comparatively light. Mordoff (1949, p. 26) stated: "The only parts of the State to receive less than

Figure 3. Mean annual precipitation. (After Mordoff, 1949)

a total of 9 inches during the three months [June, July, and August] are Niagara County, a small area in Livingston County, and the area around the head of the St. Lawrence River".

The comparatively light rainfall during the summer months does not indicate a serious moisture deficiency since the mean precipitation for the entire growing season in the St. Lawrence valley is 15 to 18 inches. The Champlain valley, eastern Mohawk valley, and most of the State west of Syracuse receive similar amounts of precipitation. There is a very narrow belt stretching from Watertown south and westward along the shore of Lake Ontario in which rainfall during the growing season is less than 15 inches.

Snowfall in the better Hungarian range is fairly heavy. It varies from 60 to 80 inches near the St. Lawrence River and increases as one proceeds southwestward. Portions of southern Jefferson County receive 140 inches or more of snow.

Lake Ontario exerts considerable influence on the climate of the region between the Adirondacks and its eastern end and, to a lesser extent, on the upper St. Lawrence valley. The effect is to temper summer and winter extremes in temperature, although springs tend to

be backward and winters severe. The growing season in the better range compares favorably in length with that for other agricultural areas of the State (Figure 4). Winter temperatures are severe, with respect both to average and minimum readings. The mean maximum temperature for January averages below 30° Fahrenheit as it does for most of the State north of the Mohawk River. Summer temperatures are moderate.

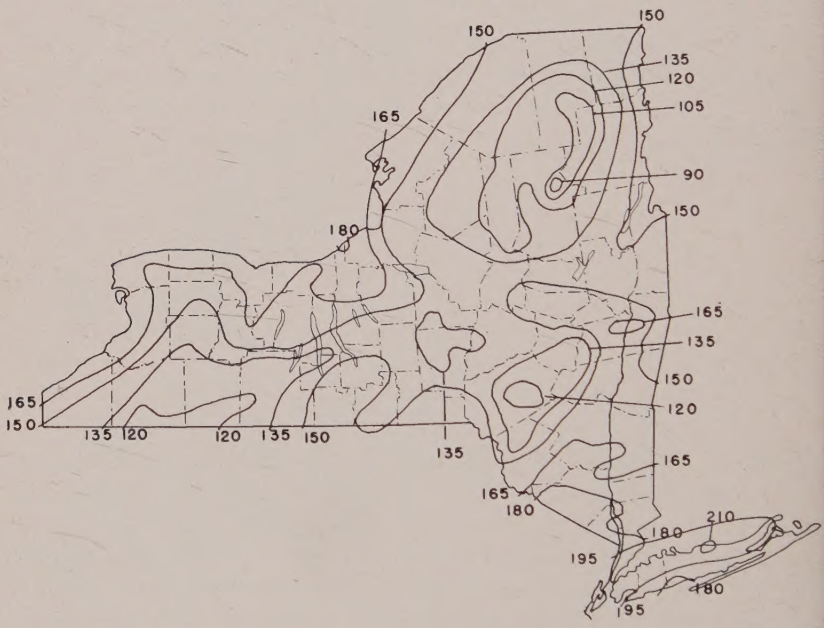

Figure 4. Average length of growing season, in days. (After Mordoff, 1949)

As a further aid in studying physical conditions in the region where Hungarians have prospered it may be said that the St. Lawrence lowland, the Lake Erie-Ontario plain, and the Mohawk-Hudson valley average considerably less than 600 feet above sea level. The Tug Hill and Appalachian plateaus average between 1,000 and 2,000 feet in elevation, and the Adirondack and Catskill highlands range from 2,000 to 3,000 feet or higher.

In attempting to analyze and correlate the information relative to climate, land use, soils, and associated factors no clearly apparent reasons were found which would explain fully the success of the Hungarian partridge in the St. Lawrence valley as contrasted with its

failure in other areas of the State where cover, food, and climatic conditions appear reasonably comparable. Consequently, it is necessary to conjecture, using the available information as a basis.

Trippensee (1948, p. 47) stated: "The sections of North America where Hungarian partridges have become well established are the great grain producing regions of the continent where natural cover is often scarce or absent. . . . This is not the ideal situation, but it serves to demonstrate the adaptable nature of the bird and suggests that small units of suitable cover well distributed help sustain a thriving population. Maximum carrying capacity is probably attained on farms devoted to the production of grain but so managed that small units of grassland, weeds, and brushy patches occur interspersed among the grainfields to provide nesting cover and protection from adverse weather and certain predators." Schrader (1944, p. 29) gives information as to the food habits of the species: "Because of its food habits, the 'Hun' finds farming lands best suited to its needs. Both corn and small grains are eaten extensively; weed seeds are used, particularly in winter when waste grains are covered by snow. Insects make up the major part of the young bird's diet; they are eaten also by the adults when available. In the spring, considerable green vegetation is taken until the new supply of seeds is ready."

As a further aid in evaluating food conditions for these birds the following information from Yocum (1943) is useful. Working in Washington, he found that grain made up 89 per cent of their fall food, and 62 per cent of their winter food. Yeatter (1934) reported similarly high proportions of grain in their diet in Michigan, and Hicks (1936) likewise found grain to be the mainstay in Ohio.

In New York's best Hungarian range the acreage in oats and mixed grains is considerable, although no more extensive than in some other parts of the State having a similar or milder climate. Most of the corn is cut for ensilage in early autumn and thus is not available for winter food. With reference to winter feeding conditions it should be pointed out that although snowfall is heavy, the wind often keeps the snow blown from the open fields to an extent that the birds can scratch for waste grain, weed seeds, and gravel. It is safe to say that a drastic reduction in grain acreage would be a serious blow to the Hungarian population.

Throughout most of the better range in the State there is ample cover both for nesting and for protection from winter winds. In fact, it is doubtful if lack of suitable cover would be a limiting factor anywhere in the State where food and climatic conditions are favorable.

One is tempted to point to the comparatively dry June weather as favoring chick survival. This certainly may be an important factor. Schrader (*op. cit.*, p. 26) pointed out that wet weather is extremely detrimental to the welfare of these birds, especially in areas of heavy clay soil. In Minnesota, he found that the species did well on the better farmlands in dry years, but decreased in rainy seasons except on the more sandy farm areas.

While snow ordinarily is not a serious matter to these birds in New York, Department records show that severe ice storms during the winters of 1942-1943 and 1946-1947 drastically reduced their numbers.

Two additional factors favor the Jefferson-St. Lawrence-Franklin County population. There is little competition with ring-necked pheasants, and hunting pressure is comparatively light. Most grain-growing areas farther downstate hold fair populations of pheasants and are combed each fall by large numbers of hunters. In view of the similarity in cover and food requirements of the two species it appears fortunate for the Hungarians that pheasants do not occur in appreciable numbers north of Jefferson County. With reference to hunting pressure, it is realized that in extensive areas of good habitat hunters may have a beneficial effect in dispersing concentrations of birds. It is doubtful, however, if the better Hungarian range in the State is large enough for this factor to be of any great importance. On the contrary, it seems likely that large concentrations of hunters such as commonly occur downstate would result in serious detriment through illegal kill. The absence of large populations of pheasants and cottontail rabbits throughout most of the range, together with the remoteness of this region from the large centers of human population, largely accounts for the low hunter pressure.

CONCLUSIONS

Reports from game management and law enforcement personnel show that the Hungarian partridge occurs in at least eight counties in New York State, with significant numbers being present only in Jefferson, St. Lawrence, and Franklin Counties. This is the only area in the State where large-scale releases during the period from 1927 to 1932 proved successful.

The most important factors favoring the increase of the species in the upper St. Lawrence valley are considered to be the dry weather which prevails during the hatching and brood seasons, the comparatively large acreage in grain crops, the existence of ample cover for nesting and shelter, the lack of competition from pheasants, and the relatively light hunting pressure in the area as a whole.

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ELECTRICAL FIELDS AS APPLIED TO THE OPERATION OF ELECTRIC FISH SHOCKERS[1]

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ABSTRACT

Experiments were conducted in an outdoor pond to determine the nature of electric fields that might be used in the operation of fish shockers. As a preliminary phase of the work, the electrical fundamentals, upon which successful use of such a shocker depends, were determined.

The paralysis voltage for brown trout (defined as the voltage, measured from the head to the tail of a fish, sufficient to stop motion instantly) was found to be 3.1 ± 0.3 volts, using alternate current.

Paralysis voltage is independent of the size of the fish, at least over a range of 3 to 11 inches.

Paralysis voltage is independent of the type of water over the tested range of water resistivity of 6,250 to 35,000 ohms per centimeter cube. Since it requires the same voltage *on the fish* to stun a large fish as a small one, a large fish, because of its greater length, may be stunned with an electrode-to-electrode voltage too low to affect a small fish.

Tentatively, the same voltage gradient required for successful alternating current shocking is believed adequate for direct current "attraction".

The resistivity of fish flesh (hatchery brown trout) is approximately 1,500 ohms per centimeter cube.

When a fish is placed in an electric field in water having a resistivity higher than that of the fish flesh, the field immediately surrounding the fish is distorted resulting in a lower voltage on the fish. The reduction in voltage in soft water (35,000 ohms per centimeter cube) makes necessary a 60 per cent increase in generator voltage to produce the same effect as in hard water (1,500 ohms per centimeter cube).

All electric shocker circuits have linear characteristics. Thus, doubling generator voltage doubles the current, and doubles the voltage in any part of the circuit.

With a typical grounded system, and an electrode 14½ feet long, 33 per cent of the generator voltage appeared in the water under the electrode, 27 per cent was lost within 2 feet of the ground bars, while the remainder was distributed in the soil between the ground bars and a point under the electrode.

Tests of various types of grounds showed that the most effective of those tried consisted of large pieces of screening laid on the bottom, and covered with soil and stones. Multiple and widely spaced grounds of any type were better than a single ground.

Tests of two-electrode systems with paddle-type electrodes showed that the electrode material (whether screening, perforated metal, or solid sheet

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metal) makes practically no difference. The larger the electrodes, the greater the separation may be. The electric field is somewhat more effective when the electrodes are held near the bottom, than when they are near the surface.

The data suggest that one may quite accurately think of each paddle-type electrode as producing an effective field around itself which is reasonably constant as electrode separation is increased. There is an effective field between the electrodes only when they are sufficiently close together that the circles of effectiveness surrounding them intersect.

One alternate-polarity-electrode system was studied and is described.

Collected data indicate that, with a system using two parallel electrodes, increasing the length of each electrode greatly increases the field strength between them.

Apparatus for measuring water and soil resistivity is described.

This paper is the third in a series resulting from a general study of the electrical method of collecting fish. It deals with a study of the electrical fields produced by the various circuits and electrode systems which have contributed to the method.

It is the conviction of the writer that extensive future progress in the electric shocker technique must depend on purely electrical developments. Progress in the past has depended largely on observations of the effect of shock on fish, which is a difficult measure for electrical effects. For this reason the electrical requirements for successful shocking have been studied, and these requirements have been expressed in electrical rather than biological form. Using these criteria the electrical characteristics of existing shocker circuits have been evaluated. Since the data collection has been tedious and time consuming, it is hoped that the findings presented here will furnish a background for developments not only by the writer but by other workers in the field.

ELECTRICAL REQUIREMENTS FOR SUCCESSFUL SHOCKING

As a preface to the study of fields, criteria were established by which the various circuits might be judged. Since large fish are easier to shock than small ones, a voltage gradient sufficient to stun 3½-inch brown trout was adopted as a minimum requirement.

Fish are shocked, not by the generator voltage nor by the total current in the circuit, but by the current which actually passes through the fish. This current is determined by the voltage between the two ends of the fish if the fish is parallel to the direction of current-flow, or by the voltage from one side of the fish to the other if it is at right angles to the direction of current-flow. For reasons which will be discussed later, the voltage gradient required to stun fish which are at right angles to the direction of current-flow has not been considered.

If it required 3 volts to stun a 3-inch fish, then the voltage gradient where the fish is to be stunned must be at least 1 volt per inch. On the other hand, since the same voltage would be required for a 12-inch fish, it would be stunned where the voltage gradient was only one-quarter volt per inch. The study of electric fields resolves itself, therefore, to determining the best methods to use to produce an adequate voltage gradient in areas where it is desired to stun fish, and to reduce the voltage losses in other parts of the circuit.

Paralysis Voltage

The voltage required to stun brown trout using 60 cycle alternating current was determined. Paralysis voltage was defined as the voltage necessary, when suddenly applied, to stop motion instantly. The voltage was measured with the long axis of the fish parallel with the direction of current-flow. A vacuum tube voltmeter was used to avoid distortion due to the current drawn by the meter. A fresh fish was used for each trial. Almost endless repetition was required to determine the exact paralysis voltage. Tests were made in a variety of waters from fairly hard spring water (6,250 ohms per centimeter cube) to soft water (35,000 ohms per centimeter cube). It was found that:

1. Over the range tested, the paralysis voltage was independent of the resistivity of the water.
2. Over the size range of 3 to 11 inches, the paralysis voltage for hatchery brown trout was independent of the size.
3. The paralysis voltage for hatchery brown trout was 3.1 ± 0.3 volts.
4. Tests with wild brown trout gave the same paralysis voltage, although too few such tests were made for the results to be conclusive.

Voltage Gradient for Direct Current

Determination of the voltage gradient required for the successful use of direct current depends on whether intermittent or steady direct current is used (Haskell *et al.*, 1954). No specific experiments were conducted to determine the required gradient, but from a few observations it appears that the minimum effective voltage gradient for intermittent direct current may be about the same as for alternating current, or about 1 volt per inch. For example, it was observed that, in a rectangular field with a uniform voltage gradient, it was possible to

draw 3½-inch brown trout using electrodes 20 feet apart with 250 volts between them. Tentatively, both alternating and direct current fields are considered adequate for electric shocking where the voltage gradient, as measured on a 3½-inch trout, is 1 volt per inch.

Distortion of Field by Presence of Fish

During the determination of paralysis voltage it was found that the presence of a fish caused distortion of the field in its immediate vicinity. The resistivity of fish flesh is lower than that of any water used. Thus, in the vicinity of a fish, the current tends to converge on and pass through the fish which presents an easier path than the water. The result is that the voltage between the head and tail of a fish is lower than the voltage between the same points would be if the fish were removed.

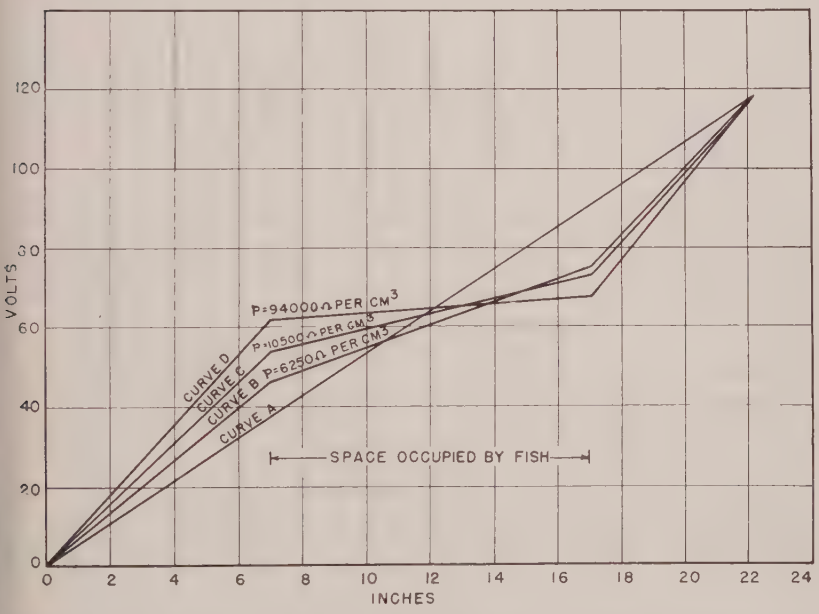


Figure 1. Distortion of electric field, for different water resistivities, caused by a 10-inch rainbow trout placed in 2 inches of water in a trough 22¼ inches long by 2 inches wide.

The distortion is illustrated in Figure 1. The data were taken by placing a 10-inch rainbow trout in a trough 2 inches wide and 22¼ inches long with a 2-inch depth of water. An electrode was

placed at either end. Curve A, taken with no fish in the trough, indicates that the voltage measured from one electrode increased linearly throughout the length of the trough. This straight line applies to all types of water used in the test. In Curves B, C, and D the voltage gradient was much less in that part of the trough occupied by the fish where it varied inversely with the water resistivity.

The amount of distortion depends to a degree on the proportion of the cross section of the current path which is occupied by the fish. In the tests with a large fish in a small trough (Figure 1), the distortion was great since the cross section of the fish represented a substantial proportion of the total cross section of the current path. It was found in stream work that, for all practical purposes, the percentage distortion was constant no matter in what part of the field the fish was placed. It is possible, then, if the resistivity of the water is known, to measure the voltage at two points 3½ inches apart and predict the voltage which would appear on a 3½-inch brown trout placed between these points. For brown trout of this size the percentages of distortion for the three types of water used in the tests are given in Table 1.

Table 1. Distortion of Electric Field by Presence of 3½-Inch Trout

Type of water	Resistivity in ohms per centimeter cube	Per cent distortion*	Voltage gradient needed to produce 1 volt per inch in fish
Hard	1,500	0.0	1.00
Moderately hard	6,250	15.0	1.18
	13,100	31.0	1.45
Soft	35,000	37.5	1.60

* Per cent distortion is defined as the percentage reduction in the voltage between two points in an electrical field in water when a fish is placed between them with its head at one point and the end of its tail at the other.

McMillan (1929) determined the "paralysis voltage" for chinook salmon. Although his findings were considered from a different standpoint than ours, on analysis his general conclusions are quite similar. McMillan found that in a given water the voltage gradient required for paralysis was inversely proportional to the length of the fish. Thus the voltage required for paralysis of a fish of any length was the same (voltage gradient x length of fish).

McMillan also found that the higher the water resistivity the higher the voltage gradient required. However, the voltage gradients measured were the electrode-to-electrode voltages divided by the electrode separation. This corresponds in our tests to the voltage gradient between two points without a fish in the field. Thus the gradient, as used by McMillan, includes the increase in voltage required to offset the distortion caused by the presence of the fish. Recognizing the fact that chinook salmon may have a quite different resistivity from that of brown trout, when the effect of distortion is considered, McMillan's data and ours are quite similar.

Electrical Resistance of a Brown Trout

A great deal of effort was expended, without success, in attempting to assign a resistance to a brown trout of a particular size. In an ordinary electrical resistor, electricity enters one end of a piece of resistor material and leaves at the other end. The resistor is surrounded by an insulating material, so that current cannot reach it except through the wires at the ends. On the other hand, a fish may be considered as a piece of electrical resistor material, but it is immersed in another resistor material (water) through which current is flowing. For this reason the effective resistance of the fish is affected by all the factors which contribute to the distortion already described. Current flowing through the water may flow through the fish as it passes it; in fact, it tends to flow through the fish in a greater density than through the water because the fish flesh offers less resistance to its flow. However, not only does the current enter the fish at the two ends but also some of it enters the sides of the fish, so that current is entering the fish at all points in the front half of the body and leaving at all points in the rear half. The amount that enters the sides of the fish, as compared with the ends, depends on the relative resistivity of fish flesh and water. In water of high resistivity most of the current will enter the fish at the ends, while in water of low resistivity the part entering the sides will be a larger part of the total. Thus the effective resistance of a fish depends on the water it is in.

Resistivity of Fish Flesh

In order to measure the resistivity of fish flesh, the distortion caused by hatchery brown trout was gradually decreased by increasing the conductivity of the water. At a water resistivity of 1,500 ohms per centimeter cube the distortion was zero. Therefore, the resistivity of fish flesh of these brown trout was 1,500 ohms per centimeter cube.

Comparison of Alternating and Direct Currents

During the period of the tests to be described, sufficient voltage measurements were made in various parts of the circuits (i.e., soil and water) to show that for practical purposes the fields produced by a direct current generator are the same in shape as those produced by a 60 cycle alternating current generator. One small difference was noted. For example, using direct current with a grounded system, the voltage was measured from the electrode at the water surface to a point in the soil directly under it. This voltage was 73 volts. The connections were then changed, to reverse the polarity of ground and electrode. The voltage was then 71 volts. Thus, a change of polarity resulted in a reduction of 2 volts in the water portion of the circuit. The effect was undoubtedly caused by polarization at the electrode. The same type of effect was noted several times in measuring voltages from the electrode to various points, but was never more than 2 volts and led to the conclusion stated above that direct current and 60 cycle alternating current fields may in practice be assumed to have the same voltage characteristics.

Effect of Change in Generator Voltage

Sufficient data were taken to warrant the conclusion that in the types of circuits used a change in generator voltage produced a proportional change in the voltage in every part of the circuit. This finding permits several conveniences in handling data. First, data may be presented as percentages of generator voltage rather than as actual volts, thus putting data taken at different voltages on a comparable basis. Second, if, for example, electrical data are taken at a generator voltage of 115 volts and it is desired to know the equivalent values for 230 volts, the latter may be obtained by doubling the voltages read at 115 volts.

CIRCUIT ANALYSES

The voltage in the test circuits to be discussed may be divided into several parts: (1) the voltage loss in the leads from the generator which, if a proper wire size is selected, is negligible and will hereafter be so considered in this paper; (2) for a grounded system, the voltage loss in the ground which includes the circuit from the ground connection through the soil to a point under the electrode; (3) the voltage drop in the water which is the useful portion of the circuit. For an ungrounded two-electrode system, the voltage in the water equals 100 per cent of the generator voltage.

Grounded System

One of the ponds at the Rome Fish Hatchery was used to test a typical grounded system. The pond averaged about 18 feet wide and 100 feet long. The water depth was adjusted to 21 inches at the electrode. A 14½-foot floating electrode made of ¼-inch mesh screening was installed, crosswise, about 12 feet from the lower end of the pond. The screening was 5 inches wide and was placed in a vertical position with the top edge one-half inch above the water surface giving it a useful depth of 4½ inches. The ground consisted of seven ¾-inch iron pipes arranged at the water edge near the upper end of the pond and driven about 18 inches into the soil. These bars were connected together. The pond had a gravel bottom 3 to 4 inches thick while the subsoil and pond banks were a heavy clay loam. The arrangement is shown in Figure 2.

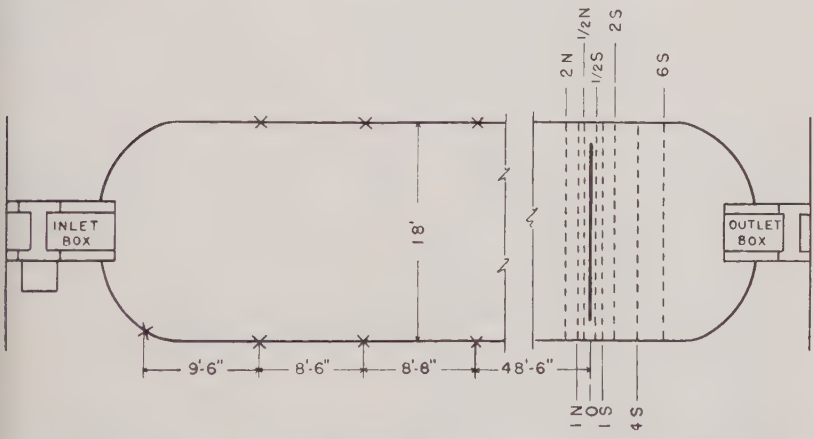


Figure 2. Plan view of area used for testing grounded system (see Figures 3 to 6) showing location of vertical sections used in recording data and of ground bars (indicated by crosses).

With the generator connected to the grounded bars and the electrode, a current of 7.95 amperes was drawn with a generator voltage of 230 volts. Approximately 67 per cent of the generator voltage was lost in the ground so that only 33 per cent was available in the water. Thus, one of the shortcomings of the grounded system is apparent. In this case the water resistivity was about 6,250 ohms per centimeter cube so that, as shown in Table 1, a voltage gradient of 1.18 volts per inch would be required. Theoretically, if 100 per cent of a generator voltage of 230 volts could be used to create a uniform

voltage gradient, the effective distance within which shocking might be done would be 230 ÷ 1.18, or 195 inches (16.25 feet). However, with only 33 per cent of the generator voltage available, the theoretical effective distance would be reduced to 5.4 feet.

Nature of Electric Field in Water Using a vacuum tube voltmeter, voltage measurements were made between the electrode and various points in the water. These points were arranged in a geometrical pattern. For example, at the surface, measurements were taken every 6 inches from shore to shore along the line passing through the length of the electrode. Similar measurements were taken at 6-inch intervals below each of these points until the bottom was reached. This pattern of measurements was repeated for similar vertical sections ½, 1, 2, 4, and 6 feet south of the electrode, and ½, 1, and 2 feet north of the electrode. Each of the sections through the water was plotted on rectangular cross section paper and the data in percentage of generator voltage were entered on the graph. Lines of equal voltage were then drawn, at intervals representing changes of 5 per cent of generator voltage, in the same manner as contour lines on a topographic map. Thus, in the accompanying graph,[2] all points on one of these lines are at the same voltage with respect to the electrode. In areas where the lines are close together the field was strong.

If a generator voltage of 230 volts is assumed, then the voltage between two equipotential lines would be 11.5 volts. Because a voltage gradient of 1.18 volts per inch would be required, the field strength would be adequate wherever the equipotential lines are not more than 10 inches apart.[3]

Considering Section 0 in Figure 3, it is noted that the field was very strong just below the electrode and became weaker as the depth increased. One might on the same graph indicate by lines the direction of current-flow. Such lines always cross the equipotential lines at right angles, so that it would be possible to visualize the direction of current-flow in various parts of the section. When such lines of current-flow

[2] Figures 3, 4, 5, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 21, 22, and 23 are all reproduced at the same scale, namely, 0.3 inch = 1 foot.

[3] Throughout this paper field strength will be judged by the requirement that equipotential lines representing a voltage change of 5 per cent be not more than 10 inches apart in areas where the effect of shocking is to be considered adequate. This standard is recognized as being severe. In such areas motion of a 3½-inch trout would be stopped instantly. Larger trout would be shocked even more severely. In somewhat weaker fields a 3½-inch trout would be stunned if it did not immediately escape.

are drawn, each line usually is made to represent a unit of current so that the closeness of the lines indicates the current density. The current lines would be close together in the same areas where the equipotential lines are close together. Thus, from observation of the equipotential lines, one can visualize the current densities. In Section 0, the current density was high close under the electrode and became lower at greater depths. That is because the current, which entered the water over a large bottom area, all converged on the electrode. Hence, for a full analysis of the field, one must study it in three dimensions.

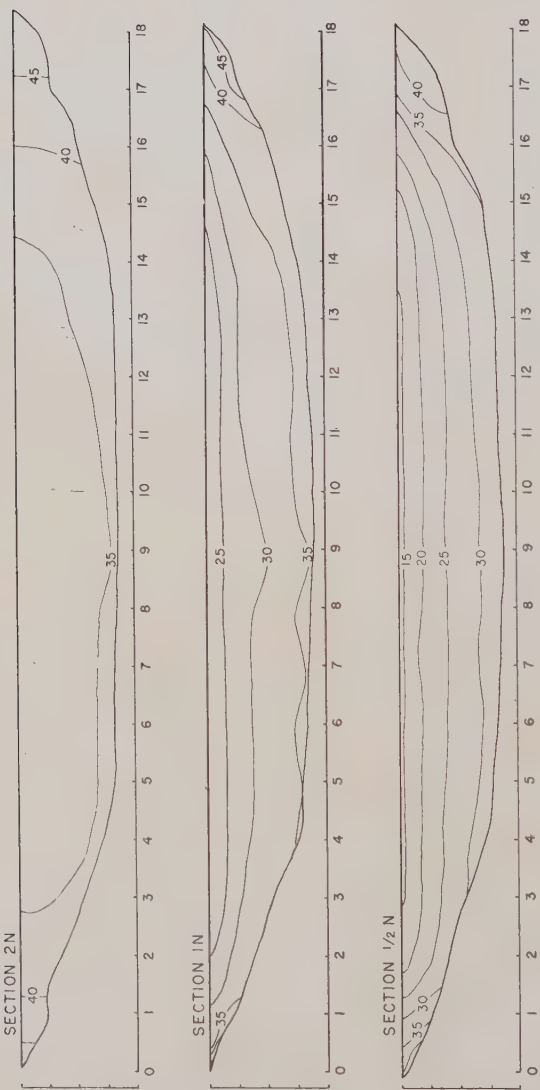
In Section 0, the field was quite similar along any vertical line from the electrode to the bottom. The current direction was straight down. Near the ends of the electrode the equipotential lines are curved as would be expected since the current passed from the ends of the electrode along the shortest paths to the less resistant soil. All areas of Section 0 were well within the requirement that the equipotential lines be not more than 10 inches apart to be effective.

Considering Sections ½S, 1S, 2S, 4S, and 6S, one finds a similar pattern of equipotential lines, the distance between the lines rapidly increasing with the distance from the electrode. Here again, this is due to the spreading of the current, as well as to the fact that the longer the water portion of the current path, the higher its resistance and the lower the resulting current density.

The graphs for Sections ½N, 1N, and 2N are quite similar to those for equidistant sections south of the electrode. In general the field strength was slightly greater on the south side of the electrode that was farthest from the ground bars. The data indicate the field strength to have been adequate within the area between the sections 1 foot either side of the electrode, but too weak at points 2 feet or more away.

In Figure 3, field strength has been analysed in a series of vertical sections of the study pond. Actually, of more interest is the voltage between the head and tail of a fish in normal swimming position which is in a horizontal plane. The field strength in a vertical plane is nonetheless quite important since it has been repeatedly observed that fish in an electric field dash about in many directions, usually until they escape or until they reach a part of the field strong enough to stop them. Thus, fish are often stopped by the vertical component of the field.

In Figure 4, the same data have been replotted to show the field configuration in horizontal planes at the surface, at depths of 6, 12, and 18 inches below the surface, and at the bottom. The graph for


SECTION 2N
SECTION 1N
SECTION 1/2 N
0
6
12
18
24
1
2
3
4
5
6
7
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16
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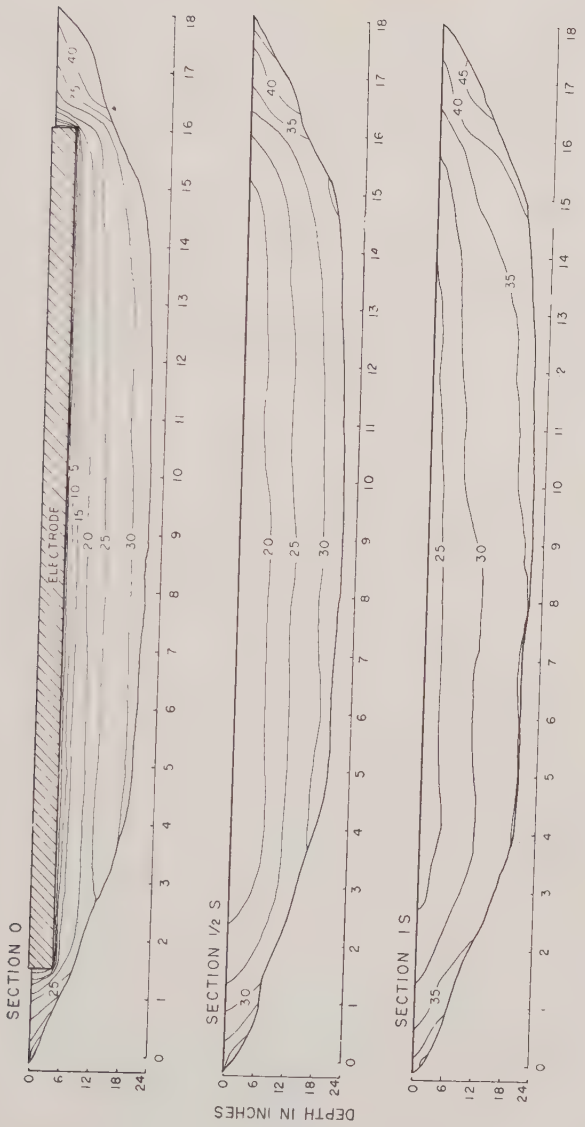
45


SECTION 0
ELECTRODE
5
10
15
20
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40
SECTION 1/2 S
20
25
30
35
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SECTION 1 S
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45
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
0 6 12 18 24
DEPTH IN INCHES

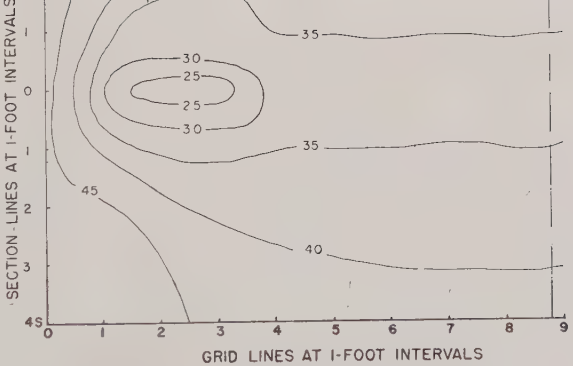

Figure 4. Lines of equipotential for horizontal sections at different water depths and for the pond bottom (not horizontal) in a grounded system.

NOTE: In Figure 4 and subsequent graphs of horizontal sections, the pond margin is shown by a heavy irregular line. That this line is farther from the centerline of the pond in the bottom section than in the ones immediately above it results from the fact that this section depicts the entire bottom curvature to the margin at the surface.

In Figure 4, heavy solid line in surface section and dotted lines in other sections indicate location of electrode. In various subsequent graphs position of electrode is indicated similarly.

the bottom does not represent a flat plane but rather the bottom curvature. Data for only one side of the centerline of the electrode have been plotted. The field was strongest in the surface section, but it became progressively weaker in each section below that. The lines are concentrated near the electrode at the surface as they were in the vertical sections. Gradients in potential were adequate for horizontal distances of 1 foot north and south of the electrode, although barely so at the bottom.

The data are presented in a third manner in Figure 5, which shows vertical sections at right angles to the electrode. Two graphs are given, one at the center of the electrode, the second 2½ feet from its west end. The spreading of the current is shown by the circular character of the equipotential lines. Considering either the vertical or the horizontal direction, the field was adequate 1 foot north or south of the electrode.

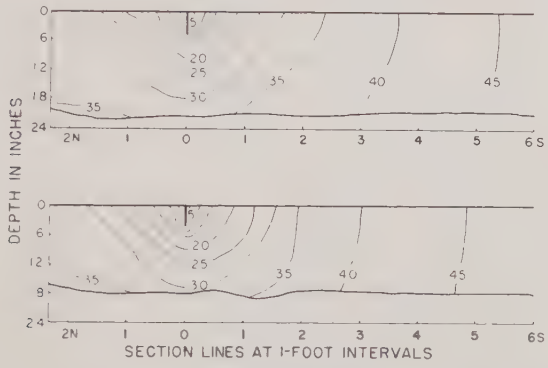

Figure 5. Lines of equipotential for vertical sections at right angles to the electrode in a grounded system: (upper) at center of electrode and (lower) at a point 2½ feet from its west end.

This grounded system provided an effective field for distances of 1 foot north or south of the electrode along any vertical or horizontal line perpendicular to it. However, an extremely slim fish might swim along an equipotential line without being shocked. Thus, as indicated by Figure 3, such a fish might cross the entire pond directly under the electrode, whereas it could not go from the downstream to the upstream side of the electrode without crossing equipotential lines and being shocked. The long-electrode grounded system, with the electrode placed transversely, thus produces an effective field to block upstream or downstream movement. Its weakness is that fish may swim parallel

to the electrode without being affected, but this is of minor importance.

The particular system discussed produced an adequate field for a maximum distance from the electrode of about 21 inches (bottom of electrode 4½ inches beneath surface to bottom of vertical section 1 foot on either side in 21 inches of water) with a generator voltage of 230 volts. Thus, the theoretical distance of 16.25 feet, which was reduced to 5.4 feet by the voltage loss in the ground as described earlier, was further reduced to 21 inches by the non-uniform character of the field which caused the equipotential lines to concentrate near the electrode. This concentration made the field too strong near the electrode and correspondingly weaker near the bottom.

Nature of Electric Field in Soil Using the same electrode and ground system, a study was made of the voltage gradients in the soil between the ground bars and the electrode. Voltage measurements were taken with a vacuum tube voltmeter between the ground bars and the end of a 2½-inch metal probe pushed into the soil. For those points which were underwater the probe was pushed into the pond bottom. The data were plotted and equipotential lines drawn, using the same intervals in percentage of generator voltage as before, with the ground bars taken as zero. The data were taken only on the west side of the centerline of the pond, Figure 6. The graph is a plan view. The data taking, of course, followed the soil surface, i.e., pond bottom, bank, and the adjacent level lawn.

The striking feature of Figure 6 is the quantitative data on the voltage loss in the immediate vicinity of the ground bars. Even though seven bars were used, about 27 per cent of the voltage was lost within 2 feet of the ground bars, while only 40 per cent was lost in the remainder of the path to the soil under the electrode. Since current-flow is at right angles to the equipotential lines, Figure 6 well illustrates the fact that most of the current traverses a path through the soil rather than the water between the ground bars and the vicinity of the electrode.

The tremendous voltage loss near the ground bars emphasizes the importance of a good ground connection. If, for example, the 27 per cent voltage loss in the immediate vicinity of the ground bars could be eliminated, the voltage lost in the soil would be approximately 55 per cent of the generator voltage and 45 per cent would be available in the water. With an increase from 33 to 45 per cent in the water, the shocker effectiveness would be greatly increased. Thus, too much emphasis cannot be placed on a good ground.

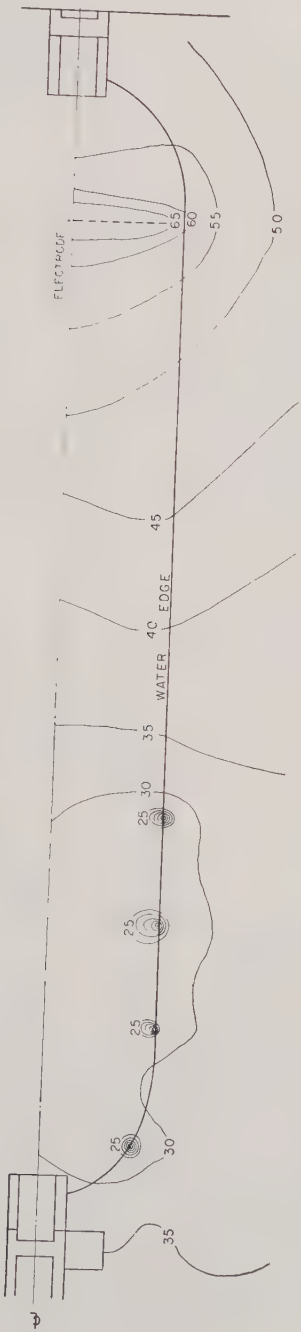

Figure 6. Lines of equipotential in the soil in relation to the location of the electrode and the ground bars in a grounded system.

Methods of Providing a Ground A series of tests were made to compare various methods of grounding. These tests were conducted in another hatchery pond having similar soil but softer water. The test layout is shown in Figure 7. The pond was about 33 feet wide. An electrode 27 feet long and 4½ inches wide was placed near the middle of the pond and at the water surface. Near one end of the pond and about 100 feet from the electrode six ground bars were driven at the water edge, three on each side 10 feet apart. In addition, six ground bars were driven and connected together outside of this rectangle, four at the corners of a concentric rectangle approximately 6 feet larger on each side and two at the midpoints of the sides crossing the pond. The plan was to use the inner rectangle of bars as a direct ground for the test and to judge the effectiveness by: (1) the current drawn by the circuit; and (2) the voltage between the direct ground and the outer rectangle of bars which thus constituted a reference for measuring the voltage lost within 6 feet of the inner ground bars.

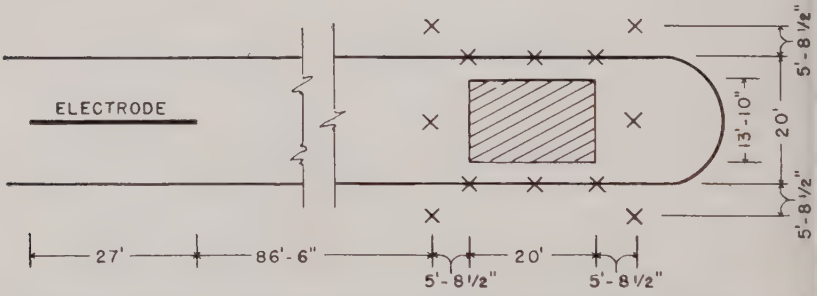

Figure 7. Plan view of area used for comparison of grounding methods showing location of ground bars (crosses) and of rectangle within which other devices were placed.

The tests were started using only one of the six bars of the inner group, then two, and so on up to six. Other ground systems were tried also, each being distributed in a rectangular area 13 feet 10 inches by 20 feet in size as shown in Figure 7. First a steel tow chain about 20 feet long was stretched out on the bottom. Then several truck tire chains interlaced with copper wire were placed as widely scattered as possible in the rectangle. Finally, two pieces of copper screening about 3½ feet square were placed on the bottom, stomped in the dirt, and loaded with several large stones.

The results, for all of these grounds, are compared in Figure 8.

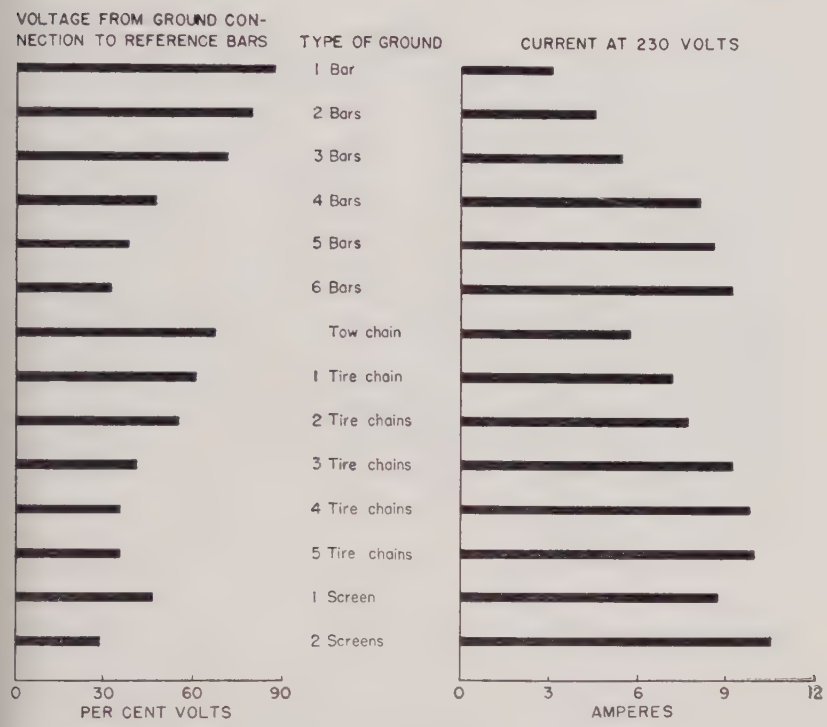

Figure 8. Comparison of grounding methods.

From the data one may conclude that:

1. Multiple grounds are an advantage over a single ground regardless of type.
2. Several pieces of screening probably provide the best and simplest ground.
3. Chains are quite satisfactory, except for practical disadvantages if they were to be carried any distance.
4. The area of contact between the ground mechanism and the soil is of great importance, since certainly the ground bars made good contact but because of the small contact area their effectiveness was more than equalled by that of the screening which probably made relatively poor contact at any particular point but had a larger area of contact.

USE OF NARROW ELECTRODES Webster and associates (Anon., 1951) reported the use of ½-inch electric shielding cable as the float-

ing electrode for a grounded system. This type of electrode has numerous advantages over an electrode made of wider screening, including less resistance to water current, elimination of breaks, and less snagging on obstructions.

From an electrical standpoint, the narrower the electrode, the greater will be the concentration of equipotential lines in its immediate vicinity with a consequent weakening of the field farther from it. In order to test the loss of effectiveness by the use of a ½-inch electrode, tests were made with the same arrangements as those illustrated in Figures 2 to 5, except that the 5-inch electrode was replaced with ½-inch shielding cable. Lines of equipotential were plotted as before, and it was found that the predicted concentration of the field near the electrode and weakening elsewhere occurred. However, the change in the field pattern was very small and it is believed the practical advantages of the narrow electrode outweigh the disadvantage of the very slight loss of effectiveness.

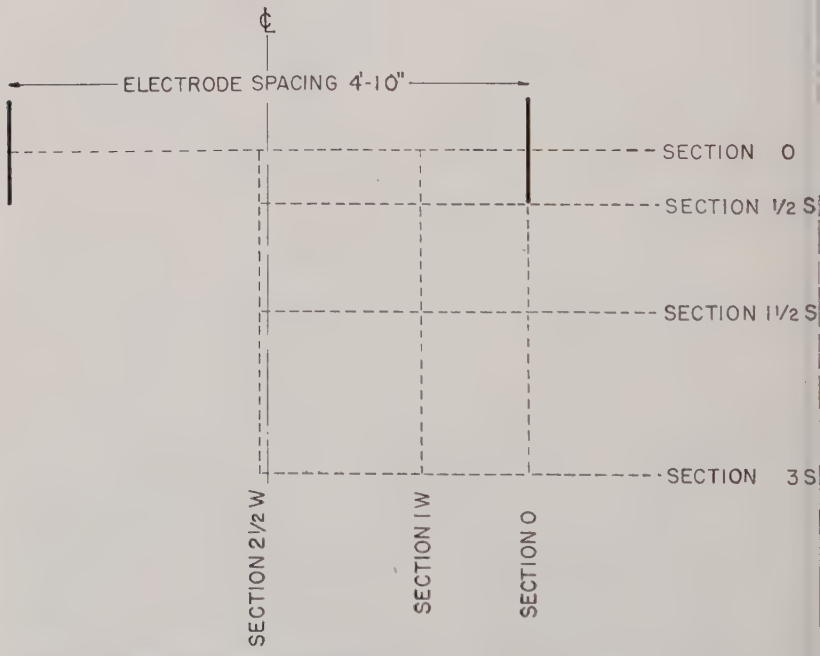

Figure 9. Plan view of arrangement for testing two-electrode system (see Figures 10, 12, 13, and 15) showing relationship of section lines along which data were recorded.

Two-Electrode System

In a two-electrode system, each generator lead is connected to one of two electrodes, which are usually of a "paddle" type. Use of such a system has been described by Shetter (1948). Ordinarily one of the paddles is held near each bank of the stream and fish are shocked between them. Thus, 100 per cent of the generator voltage is employed in the field in the water.

Nature of Electric Field Several analyses of the field produced by a two-electrode system have been made in a manner similar to that used for the grounded system. In each case, the paddles consisted of 1-foot squares of ¼-inch mesh galvanized screening. The tests were made in the same pond used for the comparison of various types of grounds. The flat surfaces of the paddles were held parallel

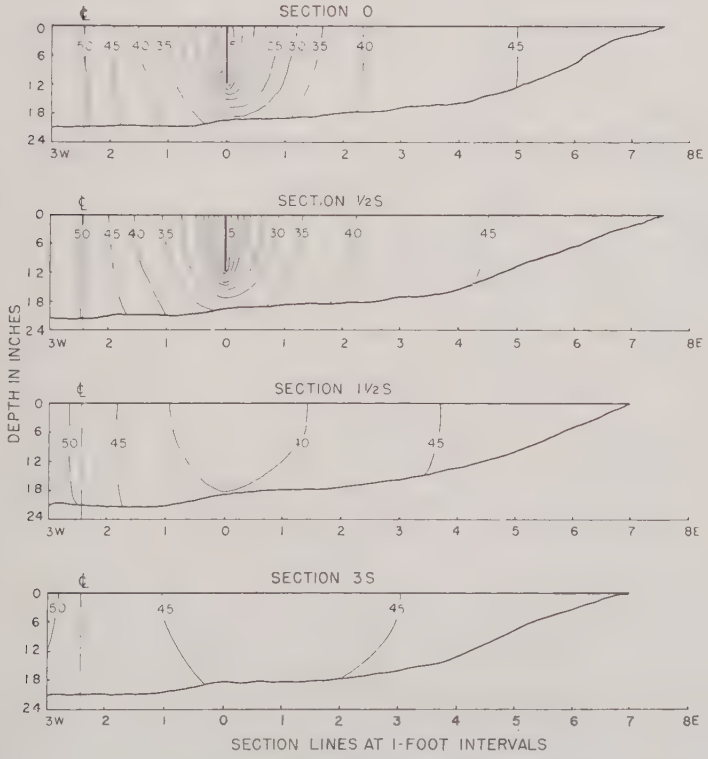

Figure 10. Lines of equipotential for vertical sections parallel to line connecting electrodes spaced 4 feet 10 inches apart with their top edges at the water surface.

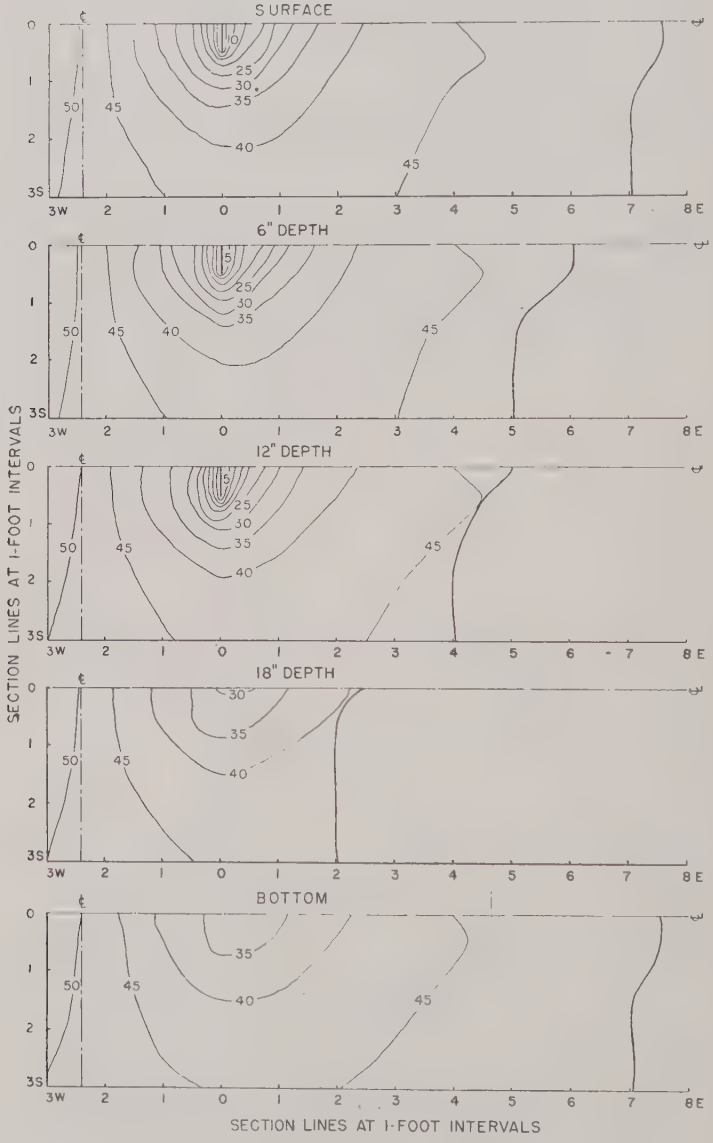

Figure 11. Lines of equipotential for horizontal sections at different water depths and for the pond bottom (not horizontal); electrodes 4 feet 10 inches apart with their top edges at the water surface.

with one another, and in the first test they were separated by a space of 4 feet 10 inches. The water depth was 21 inches. The arrangement is shown in Figure 9.

Graphs were made for only one of the four quadrants formed by a horizontal line connecting the centers of the electrodes and another horizontal line at right angles to that line and midway between the electrodes.

In Figure 10, Section 0 is a vertical section along the line connecting the centers of the two electrodes and extends to the shore. Sections ½S, 1½S, and 3S are similar at the distances indicated from the electrode. The tops of the electrodes were at the water surface. Voltages are plotted in percentage of generator voltage.

These graphs show a high concentration of the equipotential lines near the electrode and a rapid weakening as the midpoint between the electrodes was reached. There was a considerable field strength directly behind the electrode (toward shore). Downstream from the electrode the field rapidly weakened so that, judging by the 10-inch standard previously defined, it was inadequate at a distance of 18 inches. The field was weakest at the bottom.

In Figure 11, the horizontal pattern of the field is plotted at the surface, at depths of 6, 12, and 18 inches, and at the bottom of the pond. The concentration of the equipotential lines about the electrodes themselves and a weak field midway between them are again shown. The field was adequate for about 18 inches from the center of the electrode at the surface, but at the bottom it was barely adequate 1 foot away.

In Figure 12, three vertical sections are shown parallel to the face

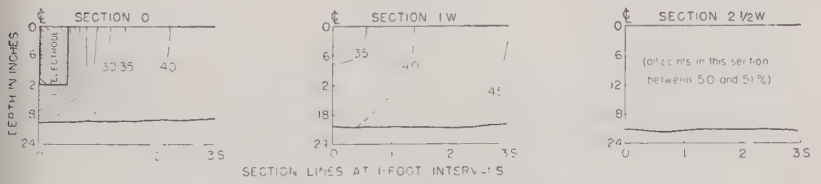

Figure 12. Lines of equipotential for vertical sections at right angles to line connecting electrodes spaced 4 feet 10 inches apart with their top edges at the water surface.

of the electrodes. Section 0 is through the electrode, while Sections 1W and 2½W are to one side as shown in Figure 9. Section 2½ is 1 inch from the midpoint between the electrodes. The comparison of these graphs is striking. In the plane of the electrode there was a

strong field for at least 2 feet beyond its end while in Section 2½W, midway between the electrodes, there was practically no change in potential.

Thus, the two-electrode system produced a strong field near the electrodes in all planes. Midway between the electrodes the field was weakest in all planes and non-existent in a plane parallel to the face of the electrode. Considering the "slim fish" mentioned before, it might readily swim through the field midway between the electrodes, which would ordinarily mean in an upstream or downstream direction. Progress crosswise of the stream would encounter a gradient in potential. One of the weaknesses of this system is the crowding of the field at the electrodes and the "hole" through the center of the field. As has been previously pointed out, fish subjected to shock rarely travel in straight lines and thus will often encounter a field if it exists in

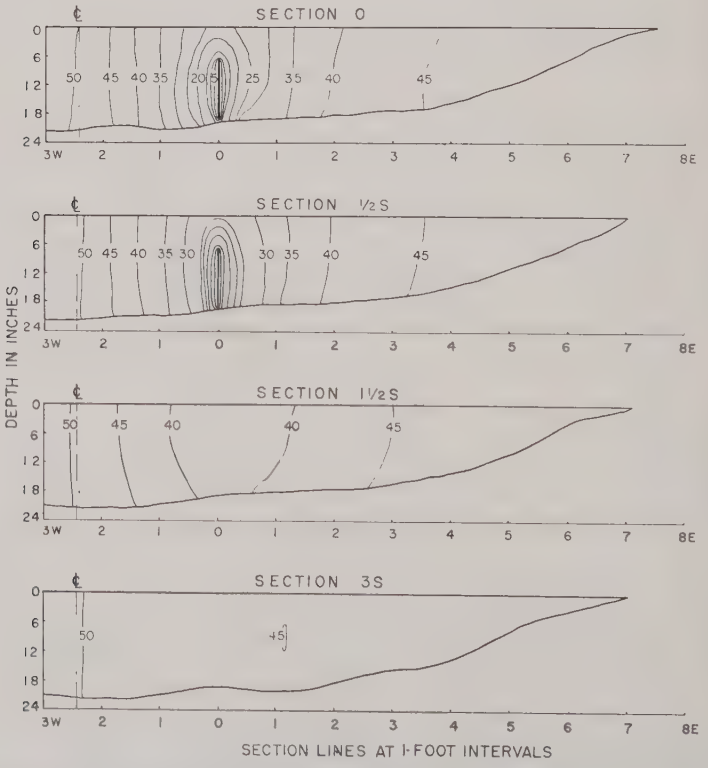

Figure 13. Lines of equipotential for vertical sections parallel to line connecting electrodes spaced 4 feet 10 inches apart with their top edges 7 inches below the water surface.

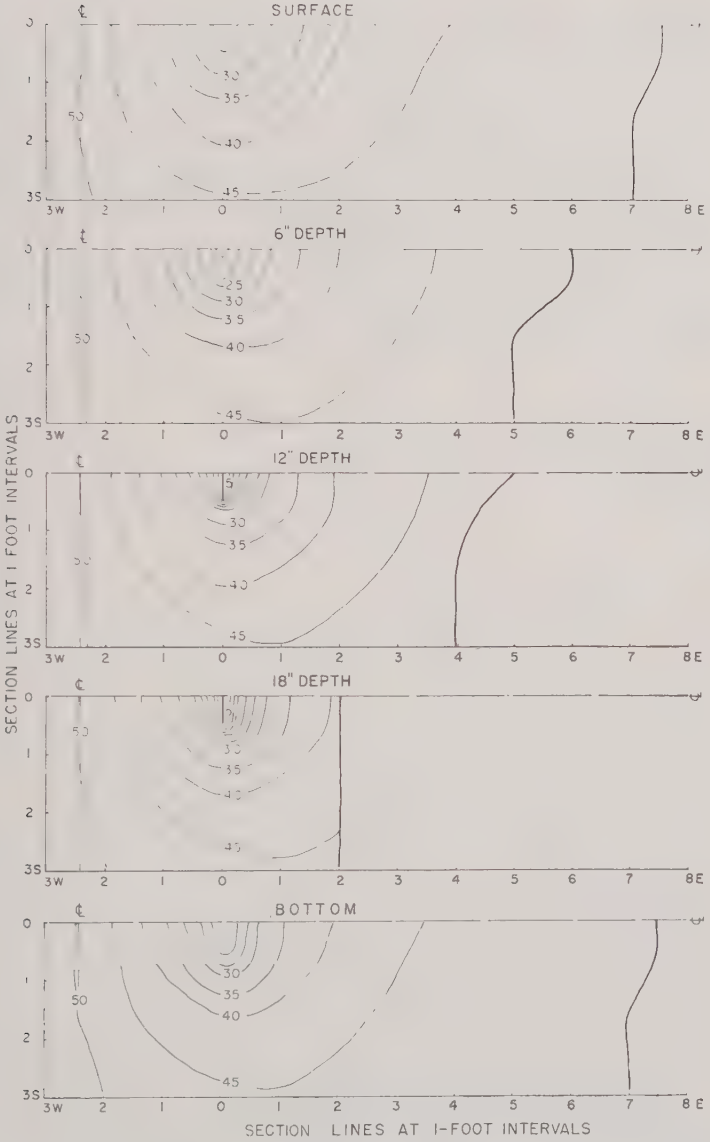

Figure 14. Lines of equipotential for horizontal sections at different water depths and for the pond bottom (not horizontal); electrodes 4 feet 10 inches apart with their top edges 7 inches below the water surface.

any direction. It is for this reason that the two-electrode system is successful.

In Figures 13, 14, and 15, data are given for a series of tests similar to the foregoing except that the electrodes were 7 inches below the surface and thus 3 inches off the bottom of the pond. The fields depicted are quite similar to those for the previous tests except that there is somewhat less piling up of the equipotential lines at the electrodes and, therefore, a somewhat stronger field between them. In the vertical sections the equipotential lines are more nearly parallel and vertical indicating a more uniform field from top to bottom. It was concluded, contrary to expectation, that for best results the electrodes may in many cases best be held near the bottom, rather than

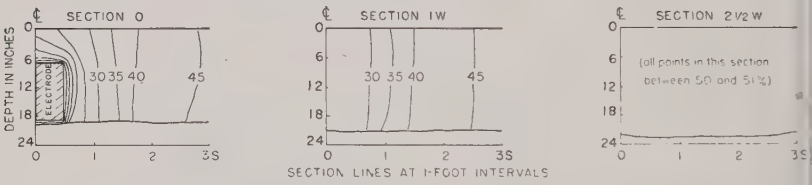

Figure 15. Lines of equipotential for vertical sections at right angles to line connecting electrodes spaced 4 feet 10 inches apart with their top edges 7 inches below the water surface.

at the surface. It may also be noted that, even with the electrodes near the bottom, the weakest point in Section 0 was midway between the electrodes and at the bottom.

A third series of tests similar to the preceding were conducted with the electrodes 9 feet 5 inches apart. The plotted data are presented in Figures 16, 17, and 18. The most notable feature is shown if Sections 0 of Figures 10 and 16 are superimposed. The fields in the general vicinity of the electrodes were very little different. The major dissimilarity occurred in the area midway between the electrodes where, with the wider spacing, the field strength was nearly nonexistent.

Roughly then, one may visualize a field surrounding each electrode which remains constant as the electrodes are separated while the field midway between them becomes weaker as the separation increases. This is, of course, due to the fact that the current spreads through a progressively larger area as the separation increases. Those with electrical training will see why, within approximate limits, a two-electrode system is almost a constant current system except for very

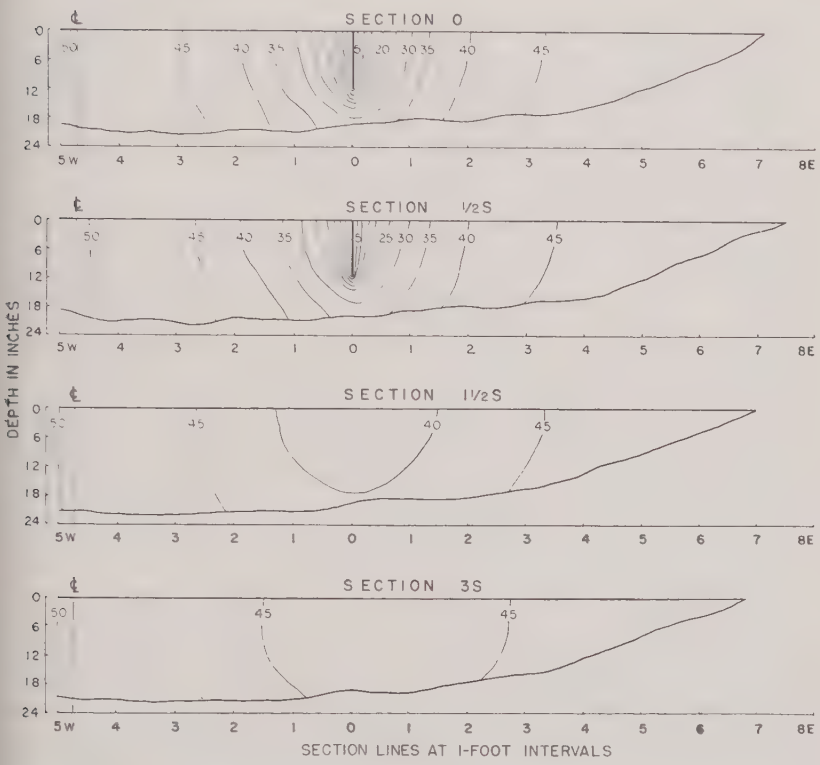

Figure 16. Lines of equipotential for vertical sections parallel to line connecting electrodes spaced 9 feet 5 inches apart with their top edges at the water surface.

small electrode separations. Users of the two-electrode system should observe the shocking effectiveness midway between the electrodes because it is here the system will fail first.

COMPARISON OF ELECTRODE TYPES The electrodes used in a two-electrode system may vary in size, shape, and material. Detailed tests covering a variety of the possible electrodes were impractical, so a simpler method of comparison was adopted. It was decided to use as a basis for comparison the generator voltage required to impress 3.1 volts on a 3½-inch brown trout placed 1 inch off the pond bottom midway between the electrodes and with its long axis parallel with a line connecting the centers of the electrodes.

Since it was obviously impractical to use a real fish in a lengthy series of tests, an artificial "fish" having most of the electrical charac-

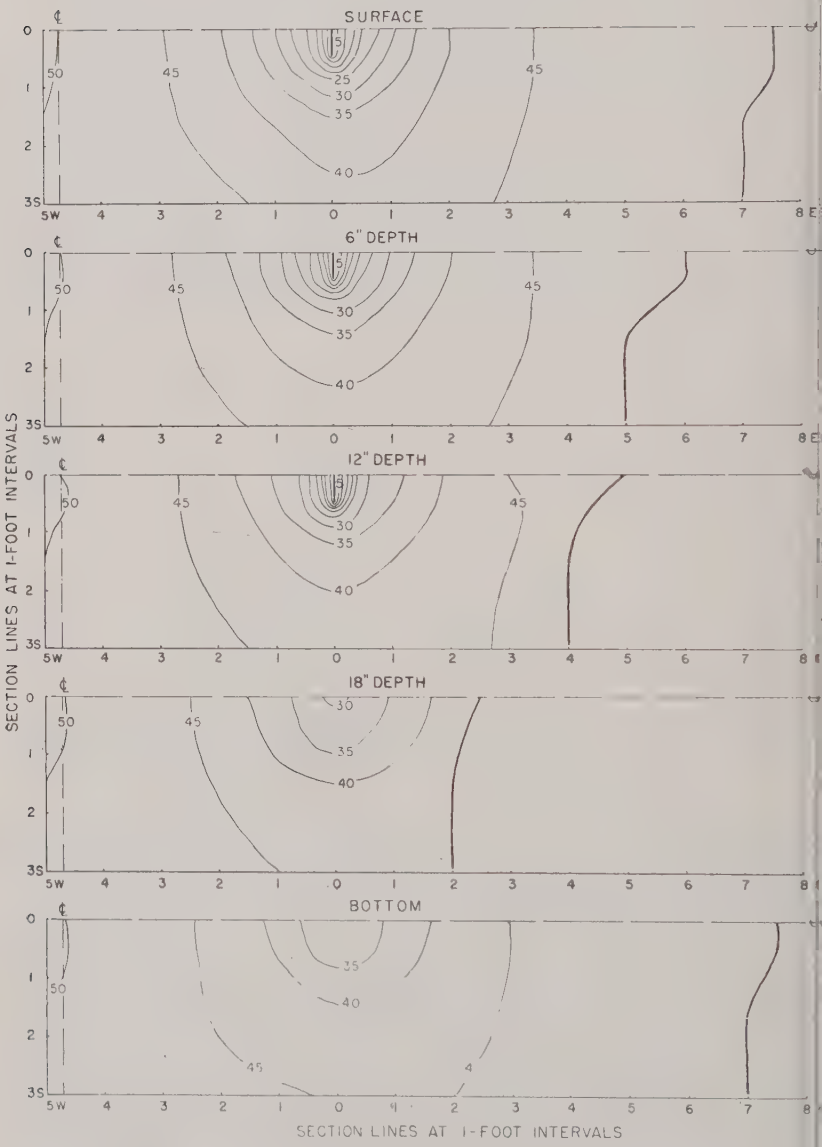

Figure 17. Lines of equipotential for horizontal sections at different water depths and for the pond bottom (not horizontal); electrodes 9 feet 5 inches apart with their top edges at the water surface.

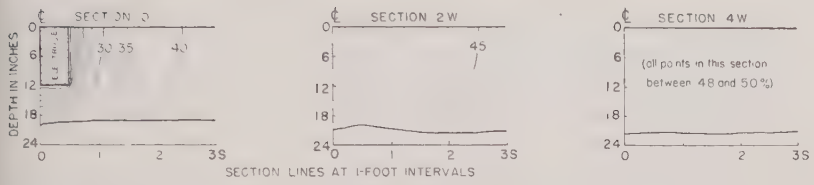

Figure 18. Lines of equipotential for vertical sections at right angles to line connecting electrodes spaced 9 feet 5 inches apart with their top edges at the water surface.

teristics of a real fish was made. To the ends of a rod of insulating material having a diameter approximately equal to the average diameter of a 3½-inch trout, thin copper discs were attached. Insulated wires were connected to the discs and brought to a vacuum tube voltmeter. A variable resistor was also connected between the two wires, thus, in effect, connecting a resistor between the two copper discs. This resistance was adjusted until the distortion produced in the water was equal to the distortion caused by a 3½-inch brown trout.

The test fish was fastened in position 1 inch off the pond bottom, and in the first test two electrodes 7 inches square made of ¼-inch galvanized screening were held at various separations and the voltage on the test fish was measured. The top edge of each electrode was at the water surface. The water depth was 21 inches. From the data the voltage required to impress 3.1 volts on the test fish was calculated and is plotted in Figure 19. Also plotted in Figure 19 are similar data taken with the electrodes at the bottom rather than the surface.

In general shape, these curves are typical of those of data for the other electrodes studied. In general, the larger the electrodes, the more nearly alike are the curves for surface and bottom positions. For the curve with the electrode at the surface, the reduction in voltage required in going from a separation of 1 foot to one of 2 feet and the increase beyond 2 feet are typical only of the smaller electrodes. This occurs because at very small separations the field does not spread enough to reach effectively the test fish at the bottom.

Since 300 volts are considered a maximum for safety of the operators, it was decided to compare electrode types by plotting the maximum separation which would impress 3.1 volts on the test fish with a generator voltage of 300. Such comparative data are given in Figure 20. For each type of electrode two bars are shown, the upper one representing the separation with the top edges of the electrodes at the surface and the lower with the electrodes touching bottom.

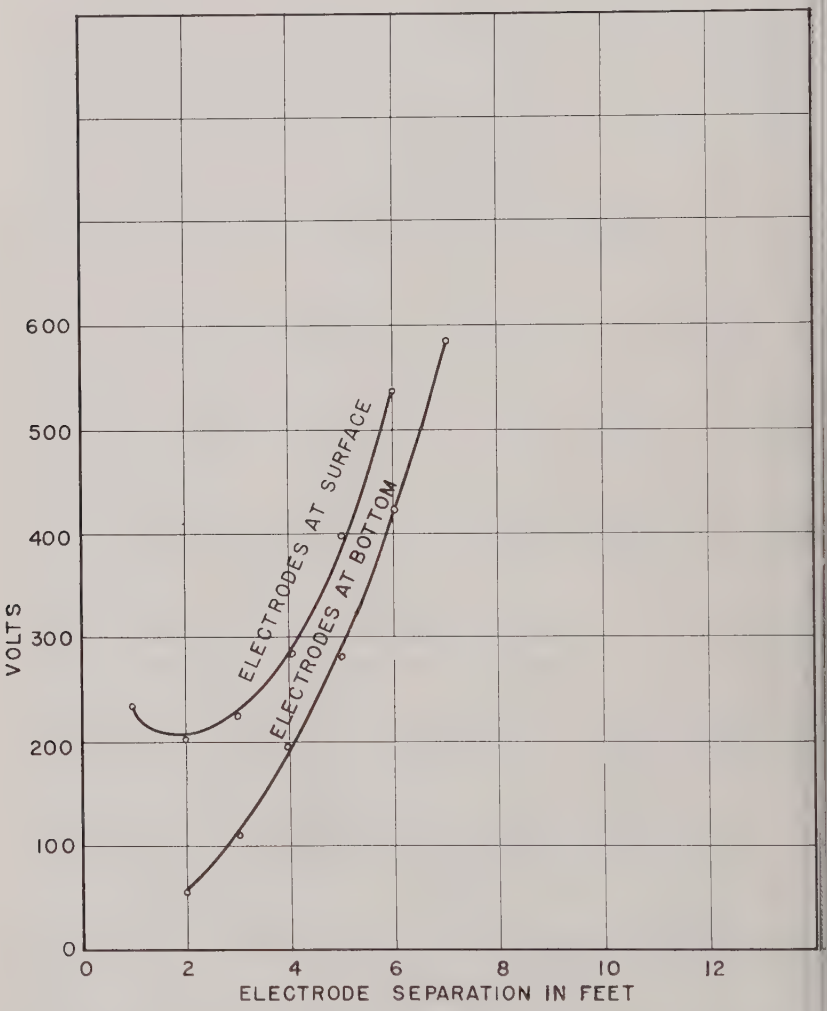

Figure 19. Electrode-to-electrode voltage required between 7 x 7-inch paddle-type electrodes to impress 3.1 volts on a 3½-inch fish located midway between them and 1 inch off the bottom in 21 inches of water with its long axis parallel to line connecting electrodes.

Some of the electrodes are designated as "framed". In these cases, a wooden strip ¾ inch square was attached to each of the four edges of each electrode so that it was impossible to touch their metal portions together. These wooden strips reduced the exposed area of the metal screening so that a 7 x 7-inch electrode when framed had an exposed surface of 6 x 6 inches.

In general, the possible electrode separation increased with the size, rapidly at first and more slowly at the larger sizes. For the test arrangement with the test fish near the bottom, all electrodes permitted a wider separation when they, too, were at the bottom.

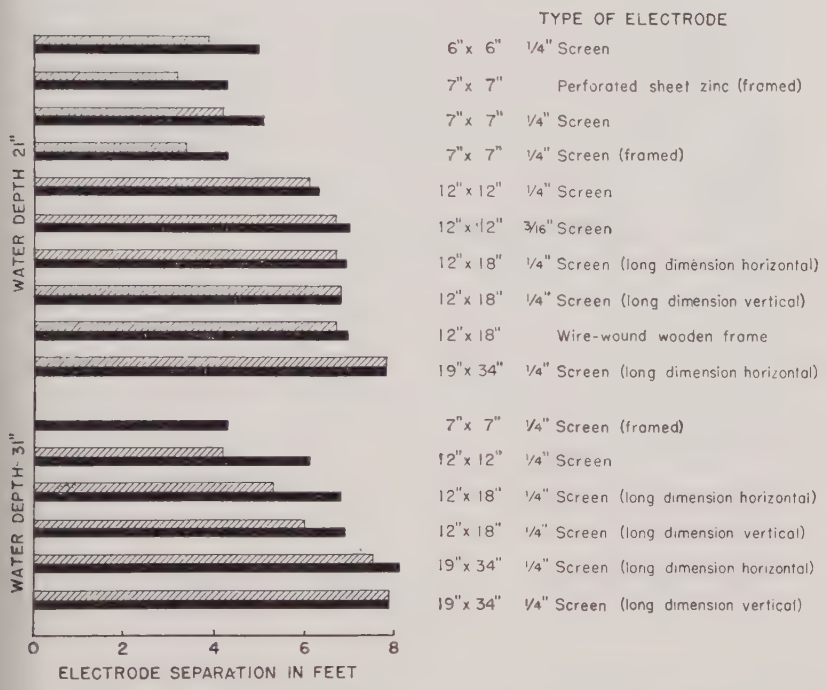
TYPE OF ELECTRODE
6"x 6" 1/4" Screen
7"x 7" Perforated sheet zinc (framed)
7"x 7" 1/4" Screen
7"x 7" 1/4" Screen (framed)
12"x 12" 1/4" Screen
12"x 12" 3/16" Screen
12"x 18" 1/4" Screen (long dimension horizontal)
12"x 18" 1/4" Screen (long dimension vertical)
12"x 18" Wire-wound wooden frame
19"x 34" 1/4" Screen (long dimension horizontal)
7"x 7" 1/4" Screen (framed)
12"x 12" 1/4" Screen
12"x 18" 1/4" Screen (long dimension horizontal)
12"x 18" 1/4" Screen (long dimension vertical)
19"x 34" 1/4" Screen (long dimension horizontal)
19"x 34" 1/4" Screen (long dimension vertical)
WATER DEPTH 21"
WATER DEPTH 31"
0
2
4
6
8
ELECTRODE SEPARATION IN FEET

Figure 20. Maximum separation for paired electrodes of different types that, at 300 volts, will impress 3.1 volts on a 3½-inch fish located midway between them and 1 inch off the bottom with its long axis parallel to line connecting the electrodes. In each case, upper bar (crosshatched) represents result with top edge of electrode at the water surface and lower bar (solid) that with electrode touching bottom. For the 7 x 7-inch electrode at the surface in 31 inches of water, 3.1 volts could not be impressed on the test fish at any separation.

When the water depth was increased the possible electrode separations were decreased, particularly for the smaller electrodes at the surface. In fact, a 7 x 7-inch electrode at the surface could not impress 3.1 volts on the test fish at any separation. In general, the larger electrodes suffered little by the increase in depth within the limits of the experiment.

Alternate-Polarity-Electrode System

Expanding the two-electrode method, several systems have been devised by various workers which employ a number of electrodes spaced across a stream and connected electrically so that they are of alternate polarity. Physically, the various electrodes are connected to a continuous support so that the whole may be manipulated by handles at the end in the manner of the long electrode of a grounded system.

Two systems of this type have been developed by New York State biologists and one of these (a version perfected by A. C. Petty) was studied. It consists of electrodes of ½-inch shielding cable, each 30 inches long and attached to a 36-inch piece of ½-inch dowel stock so that the dowel projects 3 inches beyond either end of the cable. The dowels are then attached to one another, end to end, with small straps making a flexible joint. On the ends of the two outside electrodes handles are attached. The entire electrode system is used in the same manner as the long electrode of the grounded system. The several electrodes are connected alternately to the two generator terminals so that full generator voltage appears between any pair of adjacent electrodes.

The test layout is shown in Figure 21. Voltages were measured

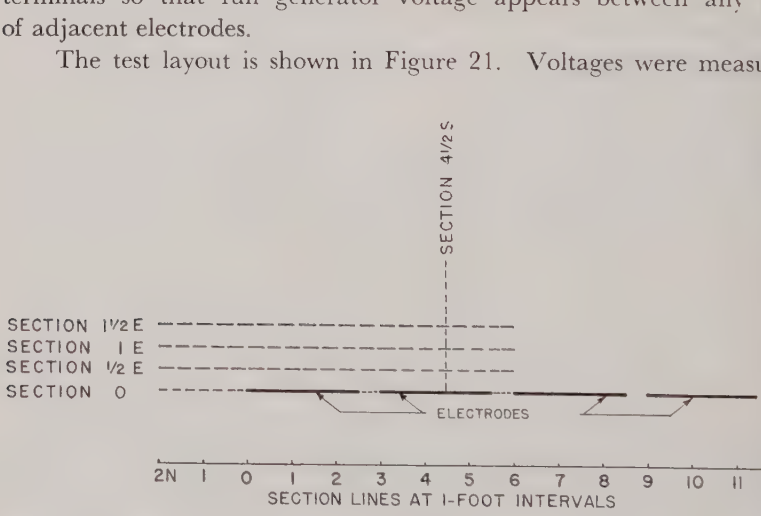
SECTION 4½ S
SECTION 1½ E
SECTION 1 E
SECTION ½ E
SECTION 0
ELECTRODES
2N 1 0 1 2 3 4 5 6 7 8 9 10 11 12S
SECTION LINES AT 1-FOOT INTERVALS

Figure 21. Plan view of arrangement for testing alternate-polarity-electrode system showing relationship of section lines along which data were recorded.

in the water with one electrode as the reference point, and equipotential lines are shown in the graphs as percentages of generator voltage. The electrode system consisted of four 30-inch sections but data were taken only for the quadrant comprising the area on one

side of two of the sections since the field would be symmetrical about the center lines. Two series of tests were made, one with the electrodes at the surface and the other with them 6 inches below the surface. Graphs are given only for the latter, since these well illustrate the fields produced.

Figure 22 shows the voltages in vertical sections parallel to the length of the electrode. In Figure 23 one vertical section in a plane perpendicular to the electrode is shown.

Section 0 (Figure 22) which passes through the long axis of the electrode shows the very concentrated field which is typical of this

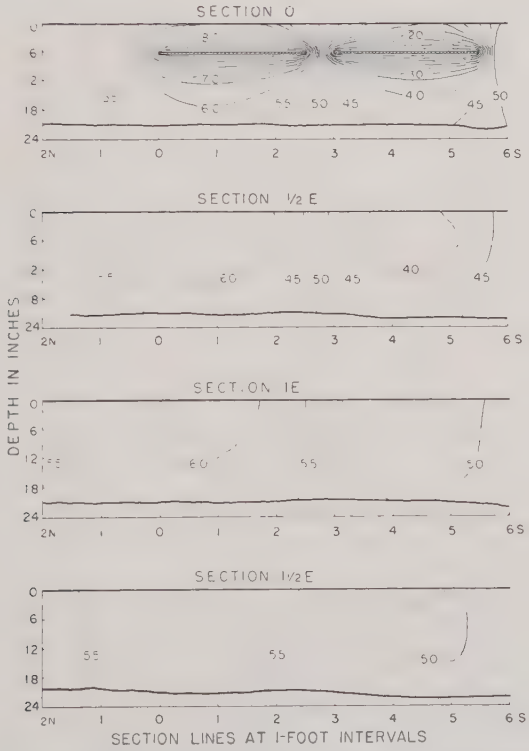

Figure 22. Lines of equipotential for vertical sections parallel to alternate-polarity electrode. Crosshatched bars in Section 0 indicate position of two units of electrode.

system in the immediate vicinity of the electrodes. Successive Sections ½E, 1E, and 1½E indicate a rapid decrease in the frequency of the equipotential lines. A casual inspection of the graphs might

lead one to believe that the field strength was dropping below effective values at very small distances from the electrodes, but this is refuted by an inspection of Figure 23 which shows a fairly extensive field of adequate intensity in a plane at right angles to the electrode axis. This

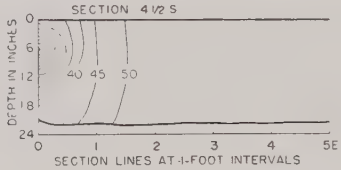

Figure 23. Lines of equipotential for vertical section at right angles to alternate-polarity electrode. Position of electrode indicated at center of concentric lines.

type of system may be thought of as producing an effective field in an area roughly 2 feet in radius surrounding the electrodes. The field is effective in blocking movements of fish past the electrodes. The comparative infrequency of equipotential lines in Sections 1E and 1½E indicates merely that the system does not block cross-stream fish movements parallel to the electrode. Thus, one may conclude that the equipotential lines constitute a highly efficient field in that they block fish movements in the desired direction, i.e., at right angles to the electrode, while voltage is not wasted in blocking cross-section movement.

The field of this system exhibits a rather straight line of 50 per cent potential about midway between the electrodes. This represents an area similar to the "hole" pointed out in the center of the field for the two-electrode system. In this case, however, the density of the field at this point would probably prohibit fish from swimming through the field along this line.

In summation, this alternate-polarity-electrode system has been found very effective in use. Theoretically, its efficiency is produced by the arrangement of the equipotential lines in a manner to prevent movements of fish in a single direction. The data also illustrate the fact that effective shocking may result from either spacing the electrodes moderately wide apart and producing a fairly uniform field, or by spacing the electrodes very close together and producing more than adequate field strength close to them for the sake of producing adequate fields farther away.

Long Parallel-Electrode System

Haskell and Zilliox (1941) described an electrode system con-

sisting of one long, narrow electrode at the water surface identical to the electrode of the grounded system, and a second long, narrow electrode consisting of a wire and located on the stream bottom several feet behind the one on the surface. The two electrodes were then parallel and approximately 6 feet apart. Somewhat similar systems have been described by Joeris (1949) and Funk (1949). More recently Holton and Sullivan (1954) have described two systems, one of which employs two long, narrow electrodes arranged parallel to one another, while the other employs several narrow, 5-foot, parallel electrodes connected to give alternate polarities.

All of these long, parallel-electrode systems have in common a valuable feature which came to the writer's attention while he was attempting to develop a deep-water pond shocker. In this study it was found that brass pipes, one-half inch in outside diameter and 8 feet long, produced an effective field between them when they were placed in water parallel to one another 6 feet apart and connected to an alternating current potential of 230 volts. It was further found that, if the electrodes was successively shortened, the effective separation was rapidly reduced. From measurements of the current drawn by electrodes of various lengths an empirical equation was developed which fitted the data rather well.

The equation consists of two terms, one constant regardless of the length of the pipes, the second proportional to the length of the electrode. The first may be considered as the current leaving the ends of one electrode, diverging into the water beyond them, and then converging on the ends of the other electrode. The second term may be thought of as the current leaving the sides of one electrode and moving in planes perpendicular to it until it reaches the second electrode. Since the current from the ends spreads in three dimensions, the equipotential lines pile up near the electrodes as they would for very small paddle-type electrodes. On the other hand, the current from the sides can spread in only two dimensions and, therefore, there is somewhat less concentration of the equipotential lines near the electrodes and a stronger field between them. With short pipes the end effects represent most of the field, but as the length of the pipes is increased the stronger field produced by the current from the sides becomes more and more important. The alternate-polarity, long, parallel-electrode system merits further consideration particularly for use in swift, shallow streams where, with the electrodes nearly horizontal and parallel to the stream course, an effective field might be produced covering several

feet of stream length so that fish would be stunned before they were swept out of the field.

WATER AND SOIL RESISTIVITY

As has already been pointed out, the resistivity of a particular water has a considerable influence on the effectiveness of a shocker due to the distortion of the field by a fish. Also, for a grounded system, the resistivity of the soil affects the proportion of the voltage available in the water. Even in an ungrounded two-electrode system, a good deal of the current passes through the soil for a portion of its path, particularly at wide electrode separations. For these reasons, a simple method of measuring the resistivities of the soil and water is very important.

A Method for Measuring Water Resistivity

Standard laboratory apparatus is available for measuring water resistivity. Such apparatus is quite expensive and is often bulky and heavy. It was planned that the apparatus to be developed should be suitable for field use, as well as simple and inexpensive, so that similar apparatus could be a practical accessory to the shocker equipment in actual stream census work. Since accuracy of the usual laboratory standard is not required for practical shocker work, it was further planned to sacrifice extreme precision in favor of simplicity.

Measurement of water resistivity is subject to several types of error, which can best be illustrated by briefly describing the test work performed in seeking a method.

The initial tests employed a conventional ohmmeter for measuring resistance. Such a meter measures resistance by the use of a direct current at an extremely low voltage supplied by a built-in battery

Two brass plates were fixed in a glass beaker, one near the top and the other at the bottom. The beaker was filled with the water to be tested, and the resistance between the plates was measured with the ohmmeter. From this resistance and the physical dimensions of the space between the plates, the resistivity of the water was calculated by use of the following equation:

$$\rho = R\frac{A}{L}$$

in which, ρ = the resistivity in ohms per centimeter cube

R = the measured resistance between the plates

A = the cross section of the current path (i.e., the beaker) in square centimeters

L = the distance between the plates in centimeters

The size of the beaker and the separation of the plates were selected so that, for the range of water to be used, the resistance read on the ohmmeter was near the center of its scale.

This method of measuring resistance gave consistent results in any particular water. The resistivities obtained increased as the tests progressed from hard to soft water, so that it seemed satisfactory. However, when the results were checked against measurements obtained with the standard alternating current bridge used for water resistivity, it was found that the ohmmeter method gave values which were about double for hard water, and that the error decreased for softer water until the readings were approximately correct for distilled water.

Subsequent tests showed that tremendous differences could be obtained by changing the electrode material. Brass, gold, aluminum, and tin were tested, both "clean" and "dirty", and wide variations in the results were obtained.

At this point, the differences between the ohmmeter and the alternating current bridge were studied. The latter uses platinum electrodes to minimize polarization in the liquid near them. Polarization depends, in part, on the metal used and in general is at a minimum for the least chemically active metals. Hence, platinum is used.

Polarization also is dependent on time, the effect increasing as the voltage is left on. The alternating current bridge uses a high frequency, usually about 1,000 cycles per second, so that the current direction reverses rapidly and, therefore, there is not sufficient time for appreciable polarization at an electrode before the current reverses and depolarization occurs.

Polarization may produce a counter emf (voltage opposing the flow of current) of as much as 2 volts. Therefore, it appeared practical to attempt to use a higher voltage for the resistance measurements than that provided by the ohmmeter. Also it seemed desirable to change to alternating current since even 60 cycles would be an improvement over direct current, and, third, a change in the electrode materials could be made.

At about this time an ohmmeter came to the writer's attention which uses either alternating or direct current voltage. The voltage may be of any value up to 115 volts. One of these instruments was obtained and used as the conventional ohmmeter had been but with alternating current which reduced polarization. Moreover, the percentage of error due to polarization was further reduced because of

the higher voltage used which, although it varied with the water being tested, was 25 volts or more across the test electrodes.

In a series of tests with this meter no differences were noted for different electrode materials. The original brass electrodes were, therefore, used in subsequent tests. The readings with the alternating current ohmmeter were the same as those taken with the standard alternating current bridge within the accuracy with which the ohmmeter could be read. This method is, therefore, recommended for field use for shocker purposes.

In subsequent tests the beaker was replaced by a bakelite box with electrodes at the end. The box was filled with water, and the resistance between the electrodes was measured. The resistivity was then calculated by the equation already given. For any particular box a factor equal to $\frac{A}{L}$ may be calculated. Consequently, the measured resistance multiplied by this factor gives the resistivity of the water.

The apparatus is shown in Figure 24. The ohmmeter is a Simplex Volt-Ohm Milliameter Model 312 made by the Chicago Industrial Instrument Company. It is definitely not a precision device as is indicated by its price of about $5.00 (in 1952). However, it is suit-

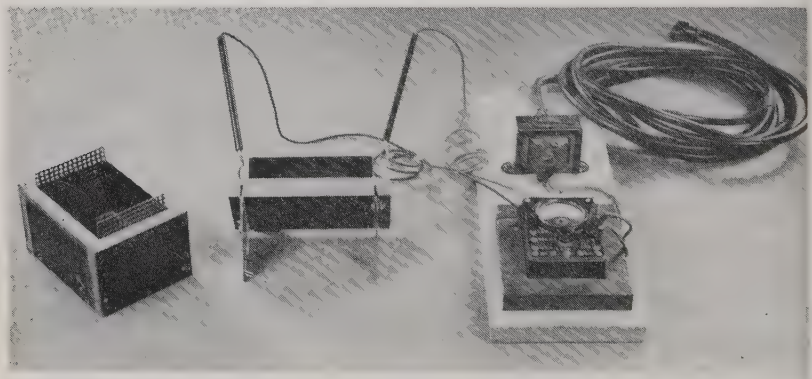

Figure 24. Equipment for measuring water and soil resistivity.

able for this use. Some caution is advised due to shock hazards. First, the full voltage being used appears across the test leads when the instrument is not connected to a resistance to be measured. Second, the terminals on the face of the meter for voltage measurements are all "hot" when it is used as a voltmeter and the instrument is not recommended for use as a voltmeter particularly around water because of these unprotected terminals. Nevertheless, it is believed satisfactory for resistance measurements with ordinary caution.

Effect of Water Temperature on Water Resistivity

The resistivity of water decreases rapidly when its temperature rises. Pender (1922) quoting Applequest and McKenny gives an empirical equation which expresses this relationship and data from the present study have been in agreement with that equation. Adapted for use with Fahrenheit temperatures, Pender's equation becomes:

$$\frac{R_1}{R_2} = \frac{4 + T_2}{4 + T_1}$$

in which, R = resistivity in ohms per centimeter cube

T = temperature in degrees Fahrenheit

A Method for Measuring Soil Resistivity

The usual method of measuring soil resistivity involves removing a soil sample for tests, with a resultant change in moisture content and degree of compaction. For shocker purposes a measure is desired for determining the resistivity of the soil as it exists at the stream. To this end, two electrodes were attached to a piece of bakelite so that they might be pushed down into the soil and kept parallel. The electrodes were actually mowing machine knives, their sharp edges permitting them to be pushed into the soil easily and their stiffness eliminating bending. This device is pictured in Figure 24. Very uniform readings were obtained in homogeneous soil.

For calibration, the test device was immersed in water of known resistivity just to the point where the bakelite reached the water surface, and the resistance between the plates was then read with the alternating current ohmmeter. From this, a factor was obtained by dividing the water resistivity by the measured resistance between the electrodes.

Once this factor is known it may be used to determine soil resistivity if the test device is pushed into the soil to the face of the bakelite. The resistivity of a soil may be obtained by multiplying the measured resistance by the factor.

Since commercial power will often be used for operating the ohmmeter, it is recommended that a 1 : 1 transformer be placed ahead of it in the circuit, the transformer output being connected to the input terminals of the ohmmeter. One of the power company wires is normally grounded. This ground will interfere with proper measurement of soil resistivity and the purpose of the transformer is to eliminate it. The transformer and ohmmeter may be mounted on a suitable base, connected together, and used permanently as so connected.

Soil Resistivity Measurements

Soil resistivity is of primary importance to the successful use of the grounded system. It is likewise important in paddle-type-electrode systems where, for large electrode separations, a very considerable portion of the current makes a part of its path through the soil. It is also important to those direct current systems which use a large, negative, floating electrode at some distance from the positive electrode, since a considerable part of the current flows from the positive electrode to the bottom, through the soil, and up to the negative electrode.

Several series of soil resistivity measurements were made. If it is assumed that the method of measurement is correct, then the interpretation of soil resistivity is difficult. It is hoped that some worker will make a more elaborate study of soil resistivity than was possible within the limits of this project.

In general, soil measurements conform to the predicted pattern based on shocker operation, i.e., where the grounded system works best, soil resistivity is lowest. In most locations, however, the variation of samples was enormous. The drier the soil, the higher the resistivity, as might be expected, but even below the water table in moist soil the variation of samples was often large.

At the Lake George Fish Hatchery, where the grounded system was first developed and where it is very satisfactory, the soil is quite uniform in resistivity. The water resistivity is 17,300 ohms and that of the soil 10,300 ohms per centimeter cube under summer temperature conditions (not measured). In this situation, with a ratio of water to soil resistivity of 1.68 : 1, the grounded system is very effective and a single ground bar is usually adequate.

At Crystal Creek, in Lewis County (N. Y.), obtaining an adequate ground is difficult. The water resistivity is 17,000 ohms and soil resistivities at stream-edge average 44,000 ohms per centimeter cube, giving a ratio of water to soil of 0.39 : 1.

As already mentioned, more study of soil resistivity and its relation to water resistivity and shocker effectiveness is needed.

CONCLUSIONS

The basic requirement for shocking fish is to establish a sufficient voltage gradient in the immediate vicinity of the fish. The required gradient varies inversely with the length of the fish, so that at any particular point in an electric field there is a minimum length of fish for which the shock will be effective. Shocker effectiveness will in-

crease proportionately as generator voltage increases, but a maximum limit of 300 volts seems reasonable from a safety standpoint.

For any electrode system, the effectiveness is greater in hard than in soft water. To obtain equivalent results in soft water, either higher generator voltage or closer electrode spacing is required. The effect of temperature on water resistivity must not be overlooked. For example, for a given water, the resistivity is approximately twice as great at 35° F. as at 78° F. Thus, from an electrical standpoint, shocking should be more difficult in winter than in summer. Temperature may well have a differential effect on the response of fish to shock, but this has not been investigated.

For the same generator voltage and electrode system, the required generator rating in amperes and watts will be inversely proportional, approximately, to the water resistivity. The rating for hard water of 1,500 ohms per centimeter cube must be twenty times that for soft water of 30,000 ohms per centimeter cube. Thus, although shocking is easier, a larger generator is required in hard water.

Considering the several electrode systems, those which produce the poorest fields would be expected to be satisfactory only in fairly hard water. Thus it might be expected that paddle-type electrodes would be satisfactory in many situations having hard water, but quite unsatisfactory in large, soft-water streams.

The grounded system, while convenient and very effective where conditions are adapted to it, has the serious disadvantage that it depends on two physical materials, water and soil, and therefore may more easily fail. It is predicted that this system gradually will be replaced by alternate-polarity, ungrounded systems except in certain especially advantageous situations. The grounded system, however, under suitable conditions, probably provides more uniform coverage of the stream-width, and is more adaptable to "reaching" beneath undercut banks and into brush than the other systems.

Alternate-polarity-electrode systems show the greatest promise for further development. Such systems may quite readily be adapted to varying water resistivities by changing the electrode separations or the generator voltage. The design of alternate-polarity systems with long, parallel electrodes offers excellent possibilities. As compared to the grounded system, these systems require a minimum of time to set up and a minimum of equipment.

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STUDIES ON THE NUTRITION OF WILD WATERFOWL[1]

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ABSTRACT

Studies were undertaken to determine whether there is a difference in the total protein requirement and animal protein requirement of surface feeding ducks and diving ducks, as well as to ascertain whether or not the nutritional requirements of wild ducks fall into the same class as those of domestic ducks.

Diets are described which produced satisfactory growth, egg production, and hatchability in wild ducks under game farm conditions. These diets are similar to those which promote excellent results in domestic ducks.

The protein requirement of young wild ducklings of several different species was found to be no greater than 19 per cent. An 8 per cent level of animal protein produced satisfactory results. A breeder diet containing 18.6 per cent protein gave satisfactory egg production and hatchability. Unsatisfactory results were obtained when a diet containing 17 per cent protein was fed with scratch grains on a free-choice basis.

In attempting to reduce feed costs a diet was studied which consisted of mixed whole grains supplemented with protein, vitamin, and mineral concentrates using molasses as a binder. This diet gave satisfactory results.

Little is known concerning the nutritional requirements of wild waterfowl. A number of surveys have been conducted (Martin and Uhler, 1939; Girard, 1941; Stoudt, 1944; Mendall, 1949; and Stollberg, 1950) on food habits of wild ducks in different parts of the country as determined by analyses of stomach contents. While these studies yield information of value to waterfowl management, they do not furnish information on quantitative nutritional requirements.

Analyses of stomach contents from black ducks in the state of Maine by Mendall showed that there is considerable variation in the relative amounts of vegetable and animal foods consumed at different localities in the state, even at the same time of the year. In the fall, approximately 85 per cent of the food was of vegetable origin and 15 per cent was of animal origin for specimens from inland fresh-water areas. In specimens from inland tidewater areas, the vegetable foods amounted to approximately 90 per cent and the animal foods to about 10 per cent. On the other hand, the food of black ducks from

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coastal water areas consisted of approximately 75 per cent animal material and only 25 per cent vegetable material. In the winter, the amount of animal food consumed by ducks from the coastal waters amounted to 87 per cent of the total diet. Examination of the stomach contents of downy young black ducks from inland fresh-water areas showed that about two-thirds of their entire diet was made up of animal foods. Insects, principally larvae, were predominant. Snails, fresh-water clams, and mussels were also found in large amounts in the diets of the young ducklings. Results of the stomach examinations, together with field observations by Mendall and associates, showed that after the ducklings were a week to 10 days old their intake of vegetable material gradually increased until by the time they were half grown their food habits were similar to those of adult ducks.

It is apparent from the studies referred to that the animal protein intake of even a single species is quite variable. When one considers the differences in feeding habits between dabbling ducks and diving ducks it must be considered probable that even greater variations in animal versus vegetable food intakes exist among the various species of wild waterfowl. The fact that the intakes of widely different types of food may vary considerably, depending solely upon the types of foods available in given feeding areas, indicates that the relative proportions of the various types of foods eaten may not be of primary importance. It appears that wild waterfowl are able to balance their diets with widely different kinds of foodstuffs, the primary considerations being the availability of sufficient protein, carbohydrates, fats, minerals, and vitamins regardless of the sources of these fundamental nutrients.

Studies with domestic fowl show that the protein requirements fall into definite classes. Chicks require only 20 per cent. For young turkeys, the requirement is in the neighborhood of 28 per cent (Scott, Heuser and Norris, 1948). On the other hand, domestic ducklings maintain satisfactory growth and development on diets containing as little as 15 to 17 per cent protein (Scott and Heuser, 1951). In all cases, best results are obtained when the diet contains some animal protein, such as fish meal, but in no instance is the amount of animal food needed in excess of 10 per cent of the diet.

The studies presented in this report were undertaken to determine the approximate total protein requirements and the animal protein requirements of wild waterfowl and to ascertain whether or not the nutritional requirements of wild ducks fall into the same class as those

of domestic ducks. These studies show that satisfactory diets for three different species during the starting, growing, and reproduction stages are not unlike diets which promote excellent results in domestic ducks.

STUDIES WITH YOUNG DUCKLINGS

Studies were undertaken to determine, first, the approximate requirement of total protein, and secondly, the approximate amount of animal protein required by wild ducklings.

EXPERIMENT 1

For the first experiment, using mallard ducklings over a 7-week growth period, the effect of a diet (D-521-S, Table 1) which was

TABLE 1. EXPERIMENTAL DIETS USED FOR STUDIES WITH YOUNG DUCKLINGS

Ingredients	Diets*		
	D-521-S	D-522-S	D-523-S
Corn meal	29.900	27.900	27.900
Wheat, ground	35.000	35.000	35.000
Oats, pulverized	15.000	15.000	15.000
Soybean meal, 44% protein	5.000	10.000	.....
Fish meal, 60% protein	8.000	4.000	16.000
Brewers' yeast, dried	2.500	2.500	2.500
Alfalfa meal, 17% protein	2.000	2.000	2.000
Dicalcium phosphate	0.500	1.500	.....
Limestone, ground	1.500	1.500	1.000
Manganese sulfate	0.025	0.025	0.025
Salt, iodized	0.250	0.250	0.250
Stabilized vitamin A supplement, 10,000 units A per gram	0.100	0.100	0.100
D-activated animal sterol, 1,500 units D_3 per gram	0.100	0.100	0.100
Riboflavin supplement, 3,600 mg. riboflavin per pound	0.050	0.050	0.050
Vitamin B_{12} supplement, 3 mg. B_{12} per pound	0.100	0.100	0.100
Niacin, per pound of above mixture	15 mg.	15 mg.	15 mg.

* All figures in percentage except those for niacin.

known to promote excellent growth in domestic ducklings was compared with that of a commercial, high-protein, game bird ration. The experimental ration contained approximately 19 per cent protein, while the commercial ration contained 28 per cent protein. Both rations were fed in pelleted form together with scratch grains on a free-choice basis. Two lots of 248 ducklings each were used. The average weight was 0.081 pound per duckling when 1 day old at the

start of the experiment. The results at 3, 4, 5, and 7 weeks of age are presented in Table 2.

Table 2. Results of Feeding Experimental Diet to Young Ducklings (Experiment 1)

Diet *	Age of ducklings in weeks			
	3	4	5	7
	Average weight in pounds §			
Ration D–521–S (19% protein)	0.94	1.38	1.88	2.62
Commercial ration (28% protein)	0.92	1.37	1.78	2.42
	Efficiency †			
Ration D–521–S (19% protein)	1.76	2.23	2.37	2.86
Commercial ration (28% protein)	2.01	2.54	2.88	3.62

* Each diet fed in pelleted form with free-choice scratch grains to 248 mallard ducklings.
§ Average weight at start was 0.081 pound.
† Pounds of feed consumed per pound of gain in weight.

These results show that diet D-521-S promoted better growth and better feed efficiency than were obtained with the commercial game bird ration and indicate that the nutritional requirements of young mallard ducklings are more satisfactorily met by the feeding of a 19 per cent protein diet together with scratch grains on a free-choice basis than through the use of a diet of higher protein content. This indicates that the protein requirement of wild ducklings falls into the same class as that of domestic ducklings.

Experiment 2

The second study was conducted to determine the optimum amount of animal protein required by three species of wild ducks. Each of the experimental diets presented in Table 1 was fed to a separate group of ducks containing approximately equal numbers of mallards, pintails, and redheads. Group 1 received diet D-521-S containing 8 per cent fish meal; Group 2 received diet D-522-S containing 4 per cent fish meal; and Group 3 received diet D-523-S containing 16 per cent fish meal. The levels of all other nutrients in these diets were maintained as nearly equal as possible. All ducklings were weighed individually at hatching and at weekly intervals throughout the duration of the experiment which was conducted over a 3-week period. The ducklings were brooded under infra-red heat lamps on

litter but had free access at all times to water for swimming. The results of the experiment are presented in Table 3.

TABLE 3. RESULTS OF FEEDING EXPERIMENTAL DIETS TO YOUNG DUCKLINGS (EXPERIMENT 2)

Diet	Average weight in pounds		
	1 week	2 weeks	3 weeks
Mallard			
D–521–S	0.32	0.61	1.12
D–522–S	0.28	0.58	0.99
D–523–S	0.26	0.55	0.98
Pintail			
D–521–S	0.39	0.71	1.03
D–522–S	0.34	0.65	0.97
D–523–S	0.31	0.61	0.86
Redhead			
D–521–S	0.23	0.46	0.94
D–522–S	0.29	0.55	0.87
D–523–S	0.24	0.51	0.75

For all three species the diet containing 8 per cent fish meal as the sole source of animal protein promoted the best growth although the results with the other diets were not markedly inferior. This indicates that the exact amount of animal protein in the diet is not critical when proper measures are taken to supply balanced amounts of protein, carbohydrates, fats, minerals, and vitamins in approximately the same amounts that have been found to be required by domestic ducklings. It is of particular interest that equivalent results were obtained with both dabbling ducks and diving ducks although their natural feeding habits differ widely.

EXPERIMENT 3

Using diet D-521-S as the control, an experiment was conducted to determine whether or not equivalent growth could be obtained with a diet composed of somewhat less expensive ingredients. The latter (D-532-S, Table 4) contained only 5 per cent fish meal, 1 per cent dried brewers' yeast, 5 per cent alfalfa meal, and 1 per cent whey. The level of barley was increased, and less corn and wheat were used

Table 4. Composition of Experimental Diet D-532-S

Ingredients	Per cent *
Barley, ground	25.000
Corn meal	20.000
Oats, pulverized	15.000
Wheat, ground	15.000
Soybean meal, 44% protein	8.750
Fish meal, 60% protein	5.000
Alfalfa meal, 17% protein	5.000
Brewers' yeast, dried	1.000
Whey product, 50% lactose, dried	1.000
Dicalcium phosphate	1.500
Limestone, ground	2.000
Salt, iodized	0.250
Manganese sulfate	0.025
Stabilized vitamin A supplement, 10,000 units A per gram	0.025
D-activated animal sterol, 1,500 units D_3 per gram	0.050
Riboflavin supplement, 3,600 mg. riboflavin per pound	0.050
Vitamin B_{12} supplement, 3 mg. B_{12} per pound	0.050
Choline chloride	0.050
Vitamin E acetate, per pound of above mixture	2.5 mg.
Niacin, per pound of above mixture	15 mg.

* Except for vitamin E acetate and niacin.

than were present in diet D-521-S. The protein level of diet D-532-S was maintained equivalent to that of D-521-S by the addition of soybean meal. The fiber content of diet D-532-S was considerably higher than that of diet D-521-S.

Approximately 21 mallard and 30 pintail ducklings received each of the experimental diets. Because of limited facilities, it was possible to carry the pintails for only 14 days, but the mallards were carried through a 3-week period. The results are presented in Table 5.

For the mallards the data indicated that diet D-521-S gave superior results both in terms of growth and in efficiency of feed utilization. However, for the pintails, equivalent growth was obtained with both rations. Feed utilization was not determined for the pintails because of the escape of two ducklings from one lot at an indefinite time during the experiment.

Experiment 4

This experiment was conducted with redhead and canvasback ducklings, comparing the growth and efficiency of feed utilization of these species for diet D-521-S as contrasted to diet D-532-S supplemented with 5 per cent dehydrated clover juice extract. The supplemented diet was designated D-533-S. The juice from clover, alfalfa, and cereal grasses has been shown by Scott (1951) and Scott and

TABLE 5. RESULTS OF FEEDING EXPERIMENTAL DIETS TO YOUNG DUCKLINGS (EXPERIMENT 3)

Diet	Average weight in pounds		Efficiency * at 3 weeks
	2 weeks	3 weeks	
Mallard			
D–521–S	0.50	0.93	2.01
D–532–S	0.46	0.81	2.55
Pintail			
D–521–S	0.60	....	....
D–532–S	0.59	....	....

* Pounds of feed consumed per pound of gain in weight.

Jensen (1952) to be required by turkey poults for optimum growth. It was the object of this experiment to determine whether or not this material in spray-dried form would increase the growth of wild ducklings. The results are presented in Table 6.

TABLE 6. RESULTS OF FEEDING EXPERIMENTAL DIETS TO YOUNG DUCKLINGS (EXPERIMENT 4)

Diet	Average weight in pounds		Efficiency * at 3 weeks
	2 weeks	3 weeks	
Redhead			
D–521–S	0.51	0.71	2.68
D–533–S §	0.60	0.82	2.82
Canvasback			
D–521–S	0.65	0.93	2.48
D–533–S §	0.65	0.90	2.94

* Pounds of feed consumed per pound of gain in weight.
§ Diet D 533 S same as diet D 532 S supplemented with 5 per cent spray-dried clover juice.

According to these results, the diet containing the spray-dried clover juice extract was at least as good for promoting growth as diet D-521-S. In view of the fact that diet D-532-S without clover juice gave results for mallards which were inferior to those obtained with

diet D-521-S, it appears possible that the addition of the clover juice was an improvement. Feed efficiency was poorer on diet D-533-S, as it was with the mallards on diet D-532-S in the previous experiment. This was undoubtedly due to the higher fibre content and, therefore, lower energy content of diets D-532-S and D-533-S as compared with diet D-521-S. It has been well established with domestic poultry that diets low in fiber and high in available energy are most efficient.

STUDIES WITH BREEDING DUCKS

Studies with breeding ducks were undertaken to determine the requirements for good egg production as well as fertility and hatchability.

Experiment 1

For the initial study an experimental diet which had been shown to promote excellent fertility and hatchability in breeding domestic ducks was fed during the breeding season to one group of captive wild ducks (Group 2) while another group received a commercial game bird feed and scratch grains as a control (Group 1). The experimental diet contained 18.6 per cent protein while the commercial diet contained 28.0 per cent protein. Each group contained 54 mallards, 8 redheads, 4 pintails, and 2 gadwalls at the start. However, when the experiment was in its eleventh day, six redheads and all the pintails and gadwalls of Group 1 escaped to Group 2. The composition of the experimental diet, designated as D-521-B, is presented in Table 7.

Table 7. Composition of Experimental Diet D-521-B

Ingredients	Per cent *
Wheat, ground	45.000
Corn meal	15.000
Oats, pulverized	15.000
Fish meal, 60% protein	7.500
Alfalfa meal, 17% protein	5.000
Skim milk, dried	5.000
Brewers' yeast, dried	3.000
Dicalcium phosphate	1.000
Limestone, ground	3.000
Salt, iodized	0.250
Manganese sulfate	0.025
Stabilized vitamin A supplement, 10,000 units A per gram	0.100
D-activated animal sterol, 1,500 units D_3 per gram	0.100
Riboflavin supplement, 3,600 mg. riboflavin per pound	0.050
Niacin, per pound of above mixture	15 mg.

* Except for niacin.

The results of the experiment over a 4-week production period are presented in Table 8. Because of the inequality in numbers of redheads, pintails, and gadwalls in the two lots after the eleventh day of the experiment, the data on egg production, fertility, and hatchability are given only for the female mallards the numbers of which remained equivalent throughout the experiment.

TABLE 8. RESULTS OF FEEDING EXPERIMENTAL DIET TO BREEDING MALLARDS* (EXPERIMENT 1)

Week	Number eggs per duck per week	Number eggs set per week	Per cent fertility	Per cent hatchability §	Pounds feed per duck per week
Commercial ration † (Group 1)					
1	4.0	167	97.0	74.1	2.50
2	5.2	209	95.7	57.0	2.20
3	4.7	202	98.0	77.8	2.65
4	3.8	164	99.4	71.8	2.45
Average	4.4	186	97.3	69.6	2.45
Diet D–521-B (Group 2)					
1	4.7	205	98.5	71.8	2.05
2	4.8	202	99.0	76.0	1.90
3	4.6	177	87.6	74.2	1.80
4	5.3	226	98.7	64.6	1.35
Average	4.8	203	96.1	71.3	1.78

* Except for rate of feed consumption, figures apply to mallards only (see text); feed consumption is given for all ducks actually present in each group.
§ For fertile eggs only.
† Plus scratch grains.

The results with the commercial feed show that egg production reached a peak at the second week and then declined during the third and fourth weeks. The amount of feed eaten per duck per week remained approximately constant at 2.50 pounds. Fertility was excellent and the hatchability of fertile eggs was 69.6 per cent over the 4-week period. On the other hand, the ducks receiving experimental diet D-521-B produced eggs at a fairly constant rate over the entire 4-week period and even increased in egg production during the fourth week when those on the commercial feed were decreasing. The average production of the ducks receiving the experimental diet was approximately 10 per cent greater than that of those receiving the commercial feed. There was also a difference in feed consumption between the

two lots. The ducks receiving the experimental diet required much less feed per week than the others. Neglecting the amount of feed eaten by the extra ducks in Group 2, those in Group 1 required approximately 37 per cent more feed than those in Group 2 and yet they produced fewer eggs. Fertility and hatchability of fertile eggs for Group 2 was approximately the same as that for Group 1.

Experiment 2

In view of the relatively good results obtained with experimental diet D-521-B, the diet of the ducks in Group 2 was changed somewhat in order to determine whether or not a simpler, and therefore less expensive, feeding ration would produce equally good results. The composition of this diet, designated D-523-B, is presented in Table 9. It contained only 17 per cent protein and was fed with free-choice scratch grains. Group 1 continued to receive the commercial game bird ration plus scratch grains.

Table 9. Composition of Experimental Diet D-523-B

Ingredients	Per cent *
Corn meal	31.000
Wheat, ground	35.000
Oats, pulverized	15.000
Alfalfa meal, 17% protein	5.000
Fish meal, 60% protein	3.000
Meat scrap, 50% protein	3.000
Brewers' yeast, dried	2.000
Whey product, 50% lactose, dried	2.000
Dicalcium phosphate	1.000
Limestone, ground	2.500
Salt, iodized	0.375
Manganese sulfate	0.025
Stabilized vitamin A supplement, 10,000 units A per gram	0.050
D-activated animal sterol, 1,500 units D_3 per gram	0.050
Riboflavin supplement, 3,600 mg. riboflavin per pound	0.050
Niacin, per pound of above mixture	15 mg.

* Except for niacin.

The results of the experiment for the subsequent 4 weeks are presented in Table 10, again using data for mallards only except with respect to feed consumption. They show that for the first 2 weeks the number of eggs laid per duck, the fertility, and the hatchability were better for Group 2 which received the experimental diet than for the other group. At the same time the amount of feed consumed per duck was much less for the experimental diet than for the commercial

TABLE 10. RESULTS OF FEEDING EXPERIMENTAL DIET TO BREEDING MALLARDS* (EXPERIMENT 2)

Week §	Number eggs per duck per week	Number eggs set per week	Per cent fertility	Per cent hatchability †	Pounds feed per duck per week
		Commercial ration ‡ (Group 1)			
5	4.1	177	97.2	60.5	2.10
6	3.3	135	85.9	55.2	2.08
7	3.1	130	83.8	42.2	1.96
8	3.1	131	78.6	47.6	1.86
Average	3.4	143	87.4	52.8	2.00
		Diet D-523-B (Group 2)			
5	4.9	214	99.1	69.8	1.30
6	4.0	166	92.8	61.7	1.90
7	2.9	127	92.1	27.4	1.57
8	2.1	89	79.8	26.8	1.45
Average	3.5	149	93.3	53.2	1.56

* Except for rate of feed consumption, figures apply to mallards only (see text for Experiment 1); feed consumption is given for all ducks actually present in each group.
§ Sequential to Experiment 1 (Table 8) in which Group 2 had been fed diet D-521-B.
† For fertile eggs only.
‡ Plus scratch grains.

feed. However, during the third and fourth weeks the hatchability of fertile eggs from the breeders receiving the experimental diet dropped off precipitously as compared with a gradual decline among the eggs from those receiving the commercial diet.

These results are interpreted to indicate either: (1) that the experimental diet D-523-B was not sufficiently adequate nutritionally to promote optimum hatchability of fertile eggs and that the good hatchability over the first 2 weeks for Group 2 was due to a carry-over of nutritional factors derived from the diet (D-521-B) previously fed to them which was more nutritionally adequate; or (2) that these ducks, being accustomed to consuming pellets, ate them largely for the first 2 weeks, but then increased their consumption of scratch grains thereby reducing their protein intake to a level too low to support adequate production and hatchability of fertile eggs.

An attempt was made to increase the hatchability of the fertile eggs produced by Group 2 through injection of isotonic solutions of vitamin B_{12} and concentrated liver extract. For this experiment, ap-

proximately 75 fertile mallard eggs were selected from a tray of eggs already incubated 14 days. They were treated as follows: the first egg was injected with 0.2 milliliter of vitamin B_{12} dissolved in physiological saline solution (equivalent to 1 microgram of vitamin B_{12} per 0.2 milliliter of solution); the second was injected with 0.2 milliliter of physiological saline solution; the third was injected with 0.2 milliliter of anti-pernicious-anemia liver extract (Eli Lilly). The remaining eggs were injected in like manner until three groups of approximately 25 eggs had been injected, each with a different one of the three solutions. The results of the experiment are presented in Table 11.

Table 11. Effect on Hatchability of Injecting Fertile Mallard Eggs with Three Solutions

Material injected	Number eggs	Number died	Number pipped	Eggs hatched	
				Number	Per cent
Vitamin B_{12} in physiological saline solution, 1 mcg. per egg	25	12	3	10	40
Physiological saline solution, only	27	8	1	18	67
Anti - pernicious - anemia liver extract (Lilly)	24	6	6	12	50

These results showed that injections of vitamin B_{12} and of liver extract into the eggs had no beneficial effect upon hatchability. Since the two major changes in the diet used in Experiment 2 were a reduction in total protein and a reduction in the level of fish meal and other sources of unknown vitamins, and since these injections did not increase hatchability, it appears most likely that the inferior results obtained with diet D-532-B were due to a lack of sufficient protein intake by the ducks receiving this diet and scratch grains.

In the course of this experiment and in other observations during the incubation work it was found that the location of the trays in the incubator appeared to have a great deal to do with the hatchability of the eggs. These observations indicate that the nearly 70 per cent hatchability of fertile eggs obtained in Experiment 1 may be the maximum which can be obtained by nutritional means and that further increases in hatchability of fertile eggs may have to be achieved by improvement in incubation procedures.

EXPERIMENT 3

The third feeding experiment with breeding mallards was conducted to compare the effects of two types of diets upon egg production, fertility, and hatchability. The diets differed in that one was a conventional pelleted mash ration while the other consisted of mixed whole grains supplemented with protein, vitamin, and mineral concentrates using molasses as a binding agent to keep the feed homogeneous. The supplemented scratch-grain ration, designated as diet D-SS-531-B, is presented in Table 12. The pelleted ration, designated as diet D-P-531-B, is presented in Table 13.

TABLE 12. COMPOSITION OF EXPERIMENTAL DIET D-SS-531-B

Ingredients	Per cent *
Wheat, whole	25.000
Corn, whole	15.000
Oats, whole	15.000
Barley, whole	15.000
Molasses, cane §	10.000
Fish meal, 60% protein	7.500
Soybean meal, 44% protein	2.500
Brewers' yeast, dried	2.500
Alfalfa meal, 17% protein	3.000
Dicalcium phosphate	1.000
Limestone, ground	3.000
Salt, iodized	0.250
Manganese sulfate	0.025
Stabilized vitamin A supplement, 10,000 units A per gram	0.150
D-activated animal sterol, 1,500 units D_3 per gram	0 100
Riboflavin supplement, 3,600 mg. riboflavin per pound	0.050
Vitamin B_{12} supplement, 3 mg. B_{12} per pound	0.050
Niacin, per pound of above mixture	15 mg.
Vitamin E acetate, per pound of above mixture	2.5 mg.

* Except for vitamin E acetate and niacin.

§ The molasses was added to the mixture of whole grains, the other materials being sprinkled onto the molasses-grain mixture during agitation in the mixer. The amount of molasses needed varies with the temperature.

One lot of breeders, 2 years of age and first generation from the wild (F_1), was fed ration D-SS-531-B while a comparable lot received diet D-P-531-B. A third lot consisting of 1-year-old mallards, second generation from the wild (F_2), was fed the pelleted diet also.

The eggs were placed in the incubators at weekly intervals beginning April 24, 1953 and extending over an 8-week period. Eggs from the three lots were placed in trays in alternate fashion so as to minimize

Table 13. Composition of Experimental Diet D-P-531-B

Ingredients	Per cent *
Wheat, ground	30.000
Corn meal	15.000
Oats, pulverized	15.000
Barley, ground	15.000
Fish meal, 60% protein	7.500
Soybean meal, 44% protein	3.000
Alfalfa meal, 17% protein	5.000
Brewers' yeast, dried	2.500
Skim milk, dried	2.500
Dicalcium phosphate	1.000
Limestone, ground	3.000
Salt, iodized	0.250
Manganese sulfate	0.025
Stabilized vitamin A supplement, 10,000 units A per gram	0.100
D-activated animal sterol, 1,500 units D_3 per gram	0.100
Riboflavin supplement, 3,600 mg. riboflavin per pound	0.050
Vitamin B_{12} supplement, 3 mg. B_{12} per pound	0.050
Choline chloride	0.050
Niacin, per pound of above mixture	15 mg.
Vitamin E acetate, per pound of above mixture	2.5 mg.
Vitamin K (menadione), per pound of above mixture	0.25 mg.

* Except for vitamin E acetate, niacin, and vitamin K.

effects of variations in incubator conditions upon the results of the nutrition studies.

The effects of these diets upon egg production and feed consumption are presented in Table 14. These results show that the ducks receiving the supplemented scratch-grain ration (D-SS-531-B) consumed 5 per cent less feed and produced 42 per cent more eggs per duck than the comparable lot receiving the pelleted mash diet. The results obtained with the F_2 ducks (Pen 1) agree in general with those obtained with the F_1 ducks in Pen 3. Thus, the markedly superior performance of the F_1 ducks in Pen 2 receiving ration D-SS-531-B appears significant.

Table 14. Egg Production and Feed Consumption of Breeding Mallards in Experiment 3 Over an 8-Week Period

Pen No.	Diet	Number ducks		Number eggs	Number eggs per duck	Feed eaten in pounds	
		Female	Male			Total	Per duck
1	D-P-531-B	24	10	127	5.29	493	14.5
2	D-SS-531-B	18	7	173	9.61	302	12.1
3	D-P-531-B	18	7	122	6.78	318	12.7

The fertility and hatchability records for the three lots presented in Table 15 show even more strikingly the superiority of the D-SS-531-B ration as compared with the pelleted ration. The lot to which it was fed showed a fertility of 91 per cent and a hatchability of fertile eggs of 74 per cent as compared with from 77 to 78 per cent fertility and 62 per cent hatchability for the two lots receiving the pelleted mash ration. Thus, the breeders on diet D-SS-531-B produced 67 per cent more ducklings than were produced by a comparable number of breeders receiving diet D-P-531-B.

TABLE 15. FERTILITY AND HATCHABILITY OF EGGS FROM BREEDING MALLARDS IN EXPERIMENT 3

Pen No.	Diet	Number eggs set	Per cent fertility	Per cent hatchability *
1	D-P-531-B	112	76.8	61.6
2	D-SS-531-B	136	91.2	74.2
3	D-P-531-B	114	78.1	61.8

* For fertile eggs only.

Except for substitution of molasses for a part of the cereal portion of the ration, and for the omission of dried skim milk, diet D-SS-531-B differed only slightly in gross composition from diet D-P-531-B. Improved results with this diet cannot be attributed to greater palatability of the SS-type ration since the ducks receiving it actually consumed less feed than those receiving the pelleted ration. An explanation of the improved results must lie in one or more of the following possibilities:

1. The ingredients used in the supplemented scratch grain ration had been subjected to relatively little processing as compared with those used in the pelleted mash. Certain nutritional factors are known to be well preserved in whole grains but may deteriorate rapidly once the grains are ground and mixed with minerals and other ingredients in a mixed feed.
2. The pelleting operation involved a heat treatment which is known to have some effect upon nutrients in a mixed feed.
3. Molasses is known to contain generous amounts of many of the necessary minerals and vitamins. It is possible that the addition of the molasses was a primary cause of the superior results obtained with the supplemented scratch grain ration.

4. There is a remote possibility that the supplemented scratch grain ration caused superior results through some obscure psychological effect upon the ducks since this type of ration is more nearly similar to the natural foods that wild ducks would encounter in their natural habitat.

It is fortunate that the supplemented scratch grain ration promoted best results because this type of ration has many advantages:

1. It is more economical.
2. It allows the full use of home-grown grains.
3. Although an appreciable amount of labor is required in mixing this type of ration, it can be prepared without the use of elaborate machinery such as pelleting equipment, grinder, etc.
4. The ingredients are exposed to less maltreatment due to processing.
5. The finished feed resembles feeds which waterfowl might find upon being released in the wild.

CONCLUSIONS

The protein requirement of young wild ducklings of several different species was found to be no greater than 19 per cent. Optimum results were obtained when the animal protein content of the diet was 8 per cent. This applied equally to mallards, pintails, and redheads, and appeared to be true also for other species. Other nutritional requirements of the various species of wild ducks appeared to be satisfied by levels of these nutrients which had been previously shown to be adequate for domestic ducklings.

Satisfactory egg production and hatchability of fertile eggs was obtained in breeding mallard ducks when a diet containing 18.6 per cent protein was used as the only feed, but unsatisfactory results were obtained when a diet containing 17 per cent protein was fed with scratch grains on a free-choice basis. Superior results were obtained through the use of a diet consisting of mixed whole grains supplemented with protein, vitamin, and mineral concentrates using molasses as a binding agent to keep the feed homogeneous.

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AN ANALYSIS OF THE FACTORS, INCLUDING POLLUTION, HAVING POSSIBLE INFLUENCE ON THE ABUNDANCE OF SHAD IN THE HUDSON RIVER

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ABSTRACT

The total reported take of shad in the Hudson River from 1924 to 1951 has been corrected for number of nets and permitted fishing hours and expressed as per cent of the average to give a value for abundance that can be readily compared year by year. Expression of the fishing pressure on a similar basis enables comparison to evaluate possible overfishing. It has been concluded that overfishing occurred when the fishing period was increased from 108 to 136 or more hours per week.

The 5-year progression of shad return has been used to show a positive relationship to change in the net lift, indicating pollution was not a factor in recent decline. Flow data for the Hudson River have also been used to show that no relationship exists between streamflow and the size of the fifth year return, further evidence that pollution is not a factor.

Oxygen data are presented for the river. Further oxygen determinations made at the time of collection of young shad have shown that young shad may be present at oxygen values even below 4.0 p.p.m. This appears to indicate that the figure given by Ellis *et al.* as a minimum for young shad may not be applicable to all natural waters. Support is given this belief by the work reported by Talbot. It is concluded that the minimum standard of 4.0 p.p.m. of oxygen for warm-water fishery waters is adequate for waters containing shad.

This Department has data available on the weight of shad taken and the amount of gear licensed for the New York portion of the Hudson River for the years from 1924 to 1951, except that the amount of gear was not recorded for 1925. The take of staked gill nets and that of drift gill nets are separated for the years after 1940.

After rising to a peak of over 2 million pounds annually in 1944 and 1945, the reported take began to fall off until in 1950 it was below a half million pounds. From time to time it has been alleged that pollution of the Hudson River may have been a major factor in this decline.

The "classification standards" for the Water Pollution Control Law in this State set a minimum of 4 p.p.m. of oxygen for water satisfactory for the support of a warm-water fishery. Ellis *et al.* (1947) have stated that shad require a minimum oxygen level of 5 p.p.m. or over. While study of waters that are somewhat deficient in oxygen in this State has indicated that a concentration of 4 p.p.m. is adequate for warm-water game fishes, the waters generally studied have not

contained shad. Further consideration of this figure as applied to waters containing shad appeared to be indicated.

The take of shad in any year reflects the effectiveness of spawning and the survival of the young from runs which occurred a number of years before. While some shad may return in their fourth year, the greatest number enter the fishery in their fifth year. Some females do not return until their sixth year.

The shad data were studied in an attempt to derive an approximate figure which could be used to represent the population. It was believed that, if such a figure could be derived, the variation in progressive year classes might support the contention that pollution was a factor in the decline, or show the reverse to be true.

CALCULATION OF ABUNDANCE

Take per unit of effort has been recognized as a valid measure of population density where there is no significant recruitment and the fishing intensity is not so great as to cause the take to enter the interval of diminishing returns.

The available data did not quite meet these conditions, as there was no record of the exact time each net was fished. It was believed that the take might be corrected for the variable number of nets licensed and for the hours per week fishing was permitted and thus a figure representative of a theoretical proportionate abundance might be derived. Further, comparison with the fishing intensity, if placed on a similar basis, might give an indication of overfishing resulting in diminishing returns.

The figure for total reported take was divided by the licensed gear multiplied by the number of hours per week fishing was permitted. This theoretical abundance value was then expressed as a percentage of the average over a specified number of years. While it lacks the accuracy which could be assumed if the fishing time for each net were available, it is believed to give a proximate value from one year to the next. It is assumed that a definite relationship existed between the population and this index and that the fishing pattern followed an approximately similar trend year to year.

As the total take is expressed in pounds, a disproportionate effect may have been exerted by dominant year classes. For a year of intensive fishing the population might appear too high, while if the gear had been operated less than usual, the population would appear to have decreased. The same tendency for the most intensive fishing to produce a high population estimate and for lower estimates to be

associated with diminished intensity would occur each year, but the values would tend to average out. It is believed that the percentage use of licensed gear during the hours fishing is permitted does not vary too greatly from year to year.

Fishing intensity is calculated by multiplying the licensed gear by the number of hours per week that fishing was permitted and corrected to a percentage of the average figure for the same years used in the computation of proportionate abundance.

The basic data for these computations and other pertinent information are given in Table 1. Figure 1 shows the values for proportionate abundance from 1924 to 1953, based on the averages for the years from 1924 to 1951. Figure 2 shows the same data in the 5-year progression of the year classes. For a better evaluation of the relationship, the take per licensed net and the fishing intensity are also presented on these graphs as percentages of the average.

These data show a very close relationship to the period of net lift[1], which affects possible fishing intensity. Under the 60-hour net lift period, the population tended to increase progressively, while change to a 32-hour lift and lift elimination during a part of the war years caused continuous decline in the estimate of abundance up to 1952, the second year an increased net lift had been in effect. Since this was associated with an increased number of nets, as well as an increase in fishing hours, the picture appears typical of overfishing with increased effort resulting in decreased take per net.

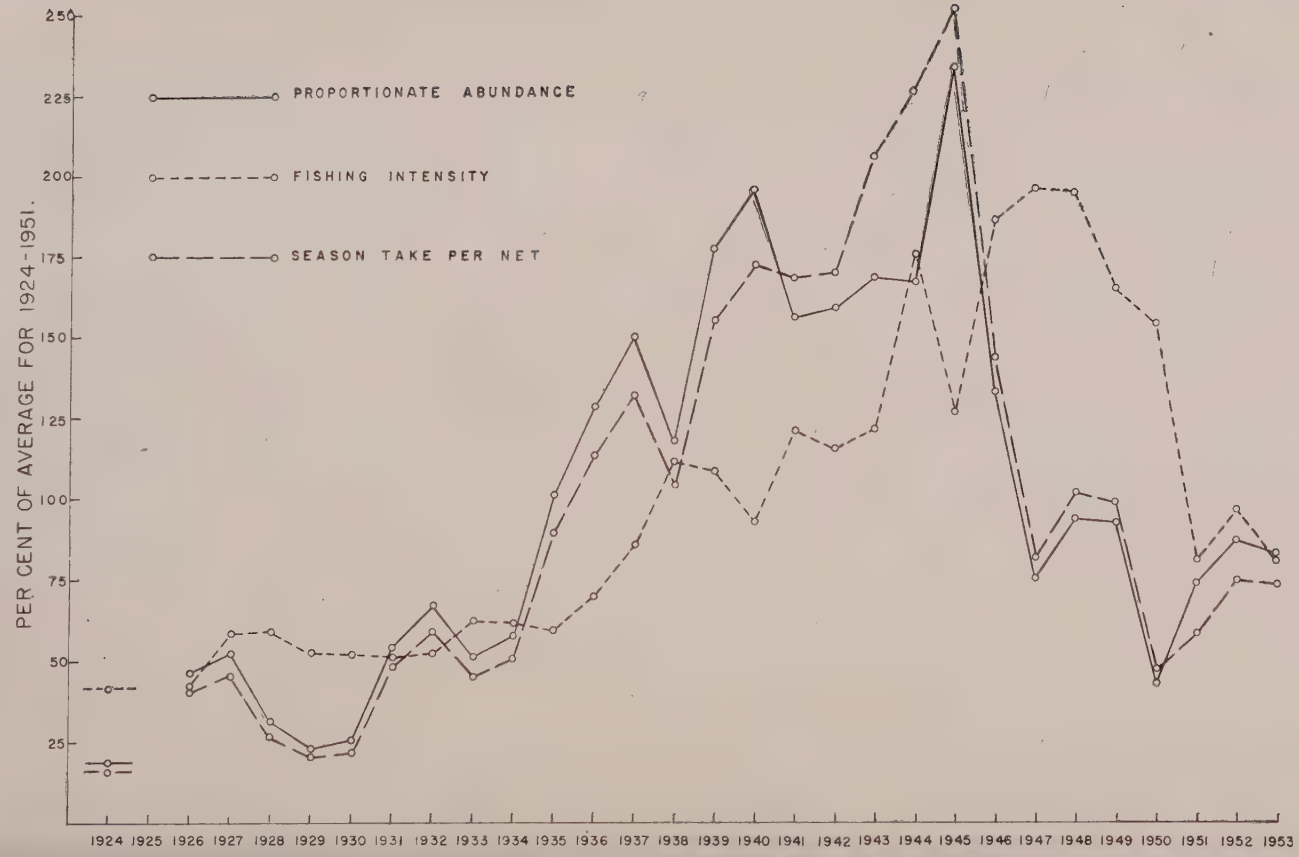
Starting with 1941, separate figures are available for the take of stake and of drift nets. Stake net data are presented in Table 2. There is considerable variation in the operation of drift nets, but the amount of fish taken by this type of gear (Table 3) indicates that it cannot be ignored without introducing bias. For purposes of comparison the data on these two types of gear are presented in Figures 3 and 4 in terms of percentage of the average for the years from 1941 to 1951 inclusive. While the trends of estimated abundance are generally similar, they do not coincide. For two of the years, the data for one type of gear indicate an increased abundance, those for the other a decrease. The drift net values appear to follow the trend shown by the combined data more closely than do the stake net figures.

The data for the two types of gear have been combined in Table 4 to give figures for fishing intensity, take per net, and abundance by a method of weighted averages and by the method of Hile (1937).

[1] Net lift is a term applied to the period set by law or regulation during which nets may not be operated.

Year	Reported catch	Average price per pound	Number nets licensed	Hours netting permitted per week	Abundance value *	Escapement §	Computed index as per cent of average		
							Fishing intensity	Take per net	Abundance
1924	55,546	24.6c	97	108	5.3	2.9	41.6	16.8	19.1
1925	87,700	22.8	?	108	?	?	?	?	?
1926	136,146	22.6	99	108	12.7	7.1	42.4	40.5	45.8
1927	211,733	19.6	136	108	14.4	8.0	58.1	45.8	52.0
1928	128,701	20.6	139	108	8.6	4.8	59.3	27.2	31.0
1929	83,395	24.0	122	108	6.3	3.5	52.2	20.1	22.7
1930	91,025	16.0	121	108	7.0	3.9	51.8	22.1	25.3
1931	195,293	14.2	120	108	15.1	8.4	51.4	47.9	54.5
1932	246,995	10.3	123	108	18.6	10.3	52.6	59.1	67.1
1933	224,582	9.9	146	108	14.2	7.9	62.5	45.2	51.3
1934	249,171	7.8	144	108	16.0	8.8	61.7	50.9	57.8
1935	425,332	9.0	140	108	28.1	15.6	59.6	89.3	101.5
1936	623,122	6.3	162	108	35.6	19.8	69.2	113.2	128.6
1937	901,585	6.4	200	108	41.7	23.2	85.4	132.6	150.6
1938	922,285	6.3	261	108	32.7	18.2	111.6	104.0	118.1
1939	1,348,527	4.7	254	108	49.2	27.3	108.4	156.1	177.7
1940	1,268,723	4.6	216	108	54.4	30.2	92.2	172.8	196.5
1941	1,322,521	6.0	231	132	43.4	11.8	120.6	168.4	156.8
1942	1,278,064	5.9	220	132	44.0	12.0	114.8	170.9	158.9
1943	1,611,751	9.4	230	150	46.7	5.6	136.5	206.2	168.7
1944	2,025,811	5.9	263	168	45.8	0.0	174.9	226.6	165.8
1945	2,077,540	13.5	242	132	65.0	17.7	126.2	252.5	234.9
1946	1,749,193	15.0	357	132	37.1	10.1	186.3	144.2	134.0
1947	1,021,617	13.4	366	132	21.1	5.8	191.1	82.1	76.3
1948	1,229,641	13.2	357	132	26.1	7.1	189.3	101.3	94.3
1949	1,064,854	14.8	315	132	25.6	7.0	164.6	99.4	92.5
1950	471,068	14.6	295	132	12.1	3.3	153.9	47.0	43.7
1951	423,473	?	215	96	20.5	15.3	81.5	57.9	74.0
1952	553,262	?	220	108	23.3	12.9‡	97.3‡	74.1‡	84.2‡
1953	456,858	?	171†	108	24.7	13.7‡	75.6‡	78.7‡	89.3‡

* Computed by dividing the reported catch by the number of nets licensed multiplied by the hours netting permitted per week.
§ Ratio between abundance value and escapement computed as equal to that between reported catch and calculated number of additional shad that would have been caught if nets had been operated continuously each week.
† The figure for 1953 is the number of nets reported as actually operated throughout the season rather than the total number licensed
‡ These figures based on average for 1924-51 period.


PROPORTIONATE ABUNDANCE
FISHING INTENSITY
SEASON TAKE PER NET
PER CENT OF AVERAGE FOR 1924-1951.
250
225
200
175
150
125
100
75
50
25
1924 1925 1926 1927 1928 1929 1930 1931 1932 1933 1934 1935 1936 1937 1938 1939 1940 1941 1942 1943 1944 1945 1946 1947 1948 1949 1950 1951 1952 1953

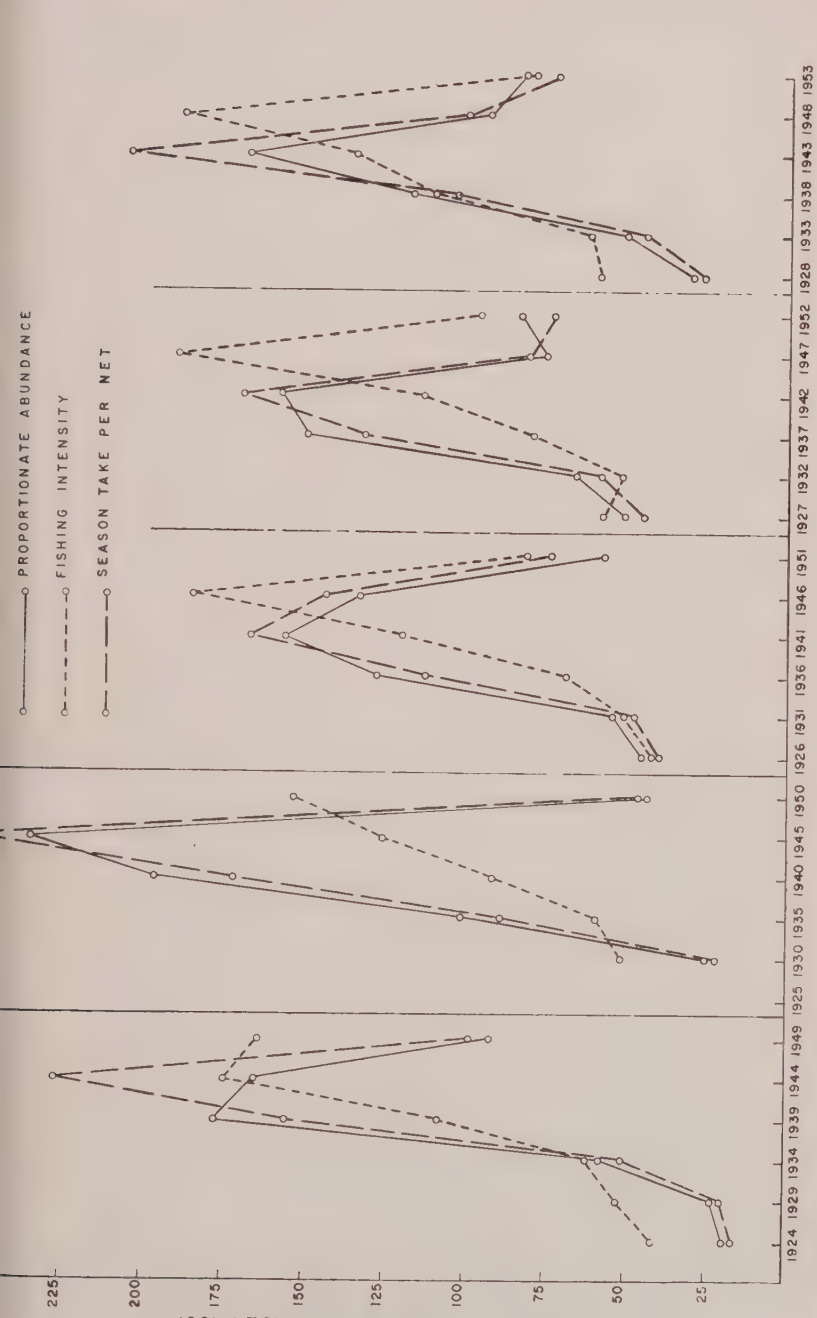


Figure 2. Yearly variations in proportionate abundance, fishing intensity, and take per net, expressed as percentages of the average for 1924 through 1951 and arranged to show the 5-year progression of year classes.

Table 2. Data Pertaining to Shad Taken in the Hudson River by Staked Gill Nets (1941-53)

Year	Reported catch	Average price per pound	Number nets licensed	Hours netting permitted per week	Abundance value *	Computed index as per cent of average §		
						Fishing intensity	Take per net	Abundance
1941	499,743	6.0c	85	132	44.5	76.4	107.6	111.4
1942	489,425	5.9	88	132	42.1	79.1	101.7	105.4
1943	614,529	9.4	97	150	42.2	99.6	116.0	105.6
1944	930,520	5.9	104	168	53.3	119.3	163.7	133.4
1945	1,000,142	13.5	98	132	77.3	88.0	186.7	193.4
1946	860,220	15.0	126	132	51.7	113.2	125.0	129.4
1947	452,593	13.4	131	132	26.2	118.0	63.1	65.5
1948	577,374	13.2	138	132	31.7	124.1	76.5	79.3
1949	661,333	14.8	126	132	39.8	113.2	96.1	99.6
1950	231,202	14.6	123	132	14.2	110.5	34.4	35.5
1951	143,453	?	90	96	16.6	58.7	29.1	41.5
1952	183,365	?	92	108	18.5	67.5‡	32.8‡	46.3‡
1953	141,603	?	77†	108	17.0	56.2‡	30.3‡	42.5‡

* Computed by dividing the reported catch by the number of nets licensed multiplied by the hours netting permitted per week
§ All percentages for years 1941-51 multiplied by a correction factor to average 100 per cent (approximately) for each column.
† The figure for 1953 is the number of nets reported as actually operated throughout the season rather than the total number licensed.
‡ These figures based on average for 1941-51 period.

Table 3. Data Pertaining to Shad Taken in the Hudson River by Drift Gill Nets (1941-53)

Year	Reported catch	Average price per pound	Number nets licensed	Hours netting permitted per week	Abundance value *	Computed index as per cent of average §		
						Fishing intensity	Take per net	Abundance
1941	822,778	6.0c	146	132	42.7	84.0	121.4	132.0
1942	789,639	5.9	132	132	45.3	75.9	128.9	140.0
1943	997,222	9.4	133	150	50.0	86.9	161.5	154.6
1944	1,095,291	5.9	159	168	41.0	116.4	148.4	126.7
1945	1,077,398	13.5	144	132	56.7	82.8	161.2	175.3
1946	888,973	15.0	231	132	29.2	132.9	82.9	90.3
1947	569,024	13.4	235	132	18.3	135.2	52.2	56.3
1948	652,267	13.2	219	132	22.6	126.0	64.2	69.9
1949	403,521	14.8	189	132	16.2	108.7	46.0	50.1
1950	239,866	14.6	172	132	10.6	98.9	30.0	32.8
1951	280,020	?	125	96	23.3	52.3	48.3	72.0
1952	369,897	?	128	108	26.8	60.2‡	62.3‡	82.8‡
1953	315,255	?	94†	108	31.1	44.2‡	72.3‡	96.1‡

* Computed by dividing the reported catch by the number of nets licensed multiplied by the hours netting permitted per week.
§ All percentages for years 1941-51 multiplied by a correction factor to average 100 per cent (approximately) for each column.
† The figure for 1953 is the number of nets reported as actually operated throughout the season rather than the total number licensed.
‡ These figures based on average for 1941-51 period.

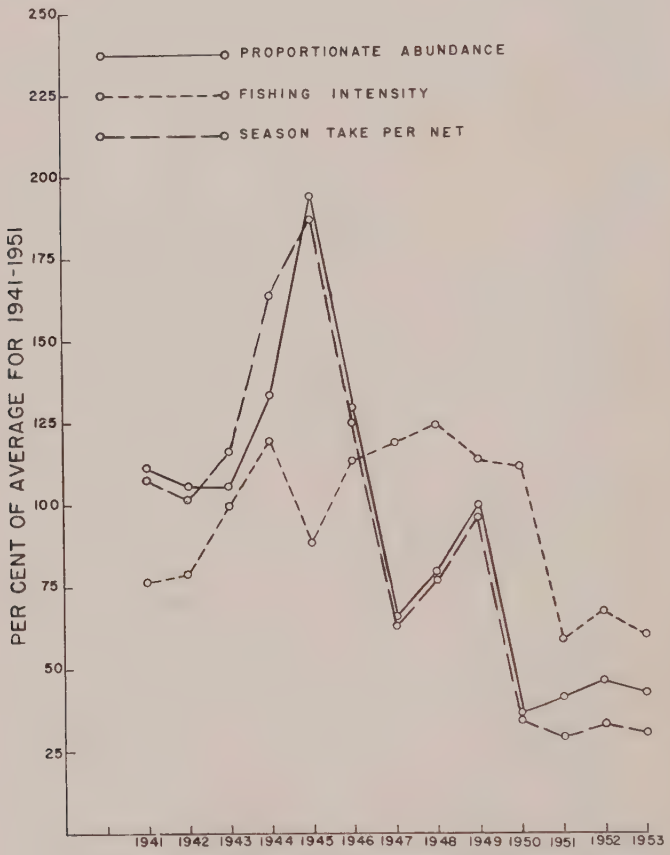


Figure 3. Yearly variations in proportionate abundance, fishing intensity, and take per net for stake nets, expressed as percentages of the average for this gear from 1941 through 1951.

Graphic presentation of the latter data as percentages of the average for the years 1941 to 1951 appears in Figure 5. It can be observed that the trend is similar to that shown in Figure 1, but, as a different base is used for the average, the lines do not coincide.

DISCUSSION

Due to the location of the fishery operations in this stream, spawning fish must run the hazard of many of the stake nets before they become available to the drift net fishermen. If a population estimate were to be based solely upon the catch in stake nets, the greater the

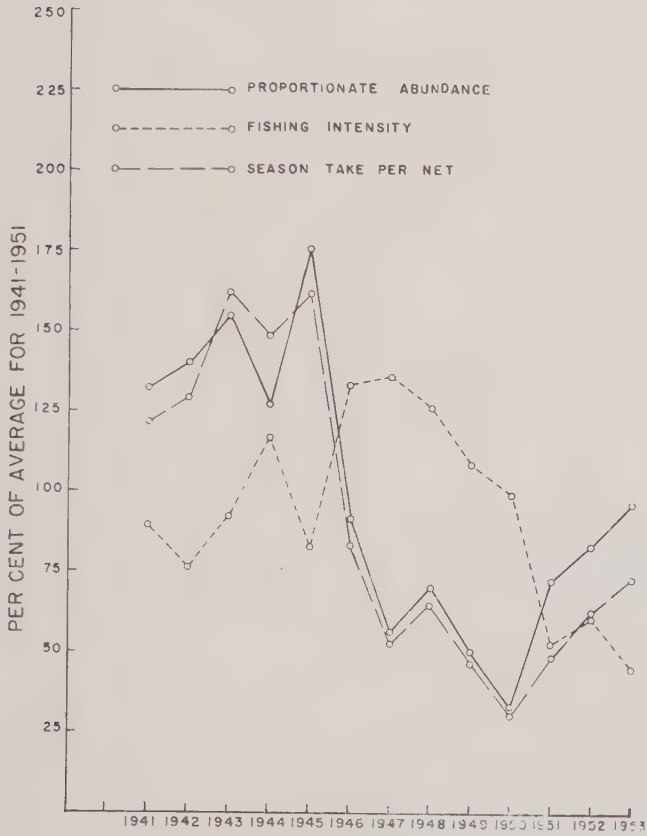


Figure 4. Yearly variations in proportionate abundance, fishing intensity, and take per net for drift nets, expressed as percentages of the average for this gear from 1941 through 1951.

lift period, the greater the possibility of an inaccurate result. The spawning run is not uniform but consists of a succession of movements. The peak of a run or some of these waves may pass the nets when they are in operation, causing too high an estimate, or when they are not, resulting in one too low.

A slight drop is found in the population estimate for 1944 compared to that for 1939. This is not sufficiently great to be considered evidence of a spawning failure, but is more probably associated with a reduction in repeat spawners as a result of overfishing in the years immediately preceding. With the exception of 1944, all runs resulting from spawning in the years of the 60-hour net lift show a continuous

Table 4. Indices* Pertaining to the Shad Fishery in the Hudson River Derived from Combined Data for Both Stake and Drift Net Operations (1941-53)

Year	Fishing intensity		Take per net		Abundance	
	After Hile§	Weighted average†	After Hile§	Weighted average†	After Hile§	Weighted average†
1941	81.2	81.0	119.5	117.3	123.8	121.8
1942	77.3	77.1	120.7	119.6	124.8	124.4
1943	91.6	91.8	145.0	145.5	131.8	133.3
1944	118.0	117.9	160.1	156.9	130.1	127.3
1945	85.4	85.3	178.1	175.1	184.1	180.5
1946	122.7	123.3	102.6	104.6	106.4	107.4
1947	127.4	127.7	58.3	57.6	60.2	59.2
1948	125.5	125.2	71.6	70.7	74.2	72.9
1949	111.8	111.6	70.2	77.8	72.7	79.3
1950	104.6	104.7	33.0	32.5	34.2	33.4
1951	54.5	54.8	40.8	42.2	57.8	60.5
1952	62.4	63.3	48.0	49.5	65.6	67.0
1953	47.3	47.9	50.6	59.3	69.1	79.5

* Expressed as percentage of average for 1941-51 period in each case.
§ Method described by Hile (1937); all figures through 1951 multiplied by a correction factor to average 100 per cent (approximately).
† Derived by combining the data used to compute the corresponding indices in Tables 2 and 3.

increase in calculated abundance. There is no evidence that the limit of the peak of production had been reached for the Hudson River. Conversely, all runs resulting from spawning during the years of the 36-hour, or shorter, net lift period showed a drop in the abundance estimate and it has been reported that large fish (repeat spawners) became very scarce during this time.

The major spawning grounds for shad are located on the flats above Kingston, though it is probable some spawning takes place on other similar areas up to and including the Stockport Middle Grounds. Closer to Albany the oxygen picture during midsummer and during low streamflows has been adverse for a long time. This section of the river lacks typical spawning areas and there is no evidence that significant egg deposition occurs, or would occur, in this region. This pollution is not believed to affect detrimentally the conditions on the usual spawning grounds.

The main effect of known pollution of the Hudson River would be due to oxygen demand. The reduced oxygen might result in the destruction of developing eggs or of the young fish. This effect would not be uniform, but, dependent upon the streamflow, would occasionally produce the nearly complete destruction of a year class. If

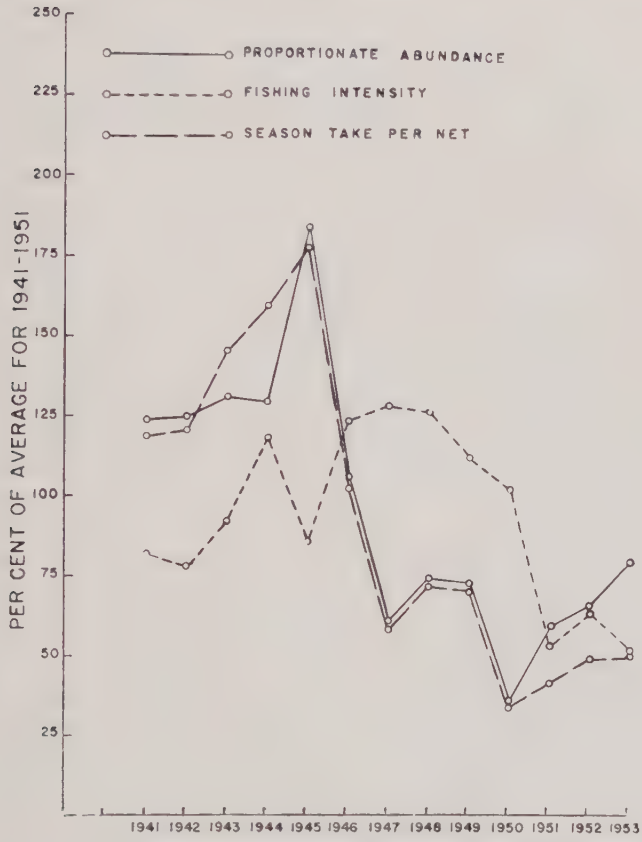


Figure 5. Yearly variations in proportionate abundance, fishing intensity, and take per net, based on the combined data for stake and drift nets and expressed as percentages of the average for 1941 through 1951.

pollution had been a significant factor during the period covered by this study, failure of a year class would have developed with a resultant sharp drop in estimated abundance.

If the picture of progressive increase and then decline which is presented by the graphs of proportionate abundance is to be linked to pollution, it is necessary to assume that in the exact year of the change from a 60- to a 36-hour net lift, pollution suddenly became sufficiently aggravated to affect the fishery seriously. It must also be assumed that it had no serious effect throughout the preceding 17 years when the 60-hour net lift was in effect. Further, the pollution would thereafter

have to have been maintained at a level which would have seriously restricted the productivity of shad in the Hudson River, either by effect on the eggs or on the survival of the young fish. In a stream of such variable flow, it is impossible to accept any premise that the pollution could have been maintained so uniformly that spawning, sufficiently successful to reverse the decline in the fishery, could not have occurred in at least one of the years.

No such difficulty in interpretation is present if the decline is assumed to be the result of overfishing and too small an escapement to the spawning grounds. The slight increase in abundance in 1952 can be accounted for on the basis of increased escapement permitting a greater number of repeat spawners to return to the stream, increasing the poundage, though not necessarily the number of fish, in the fishery. Unfortunately, it has not yet been possible to observe the effect of the 72- and 60-hour net lift periods. While some slight effect may be seen in 1955, the major influence on the year classes will not be noted until 1956 and 1957.

It was noted that the abundance figures given here do not check too closely with the estimates made in the progress reports of the U. S. Fish and Wildlife Service (1951, 1952) for the 1950 and 1951 seasons. Their calculations were based on returns from tagging at the mouth of the river and on the spawning beds. For one of the years the majority of cooperators operated stake nets. Furthermore, drift net operators were not sufficiently represented among the cooperators to equal the proportion indicated by the licensing records. Thus, a disproportionate emphasis appears to have been given to the stake net catch.

It is believed that the method used here for computing an estimate of abundance has at least as high a possibility of accuracy as the computation from the 1950 and 1951 tagging. The usual method of computation based on tag returns (such as may be used in studying a lake fishery) cannot be assumed to give an accurate figure for an anadromous spawning population. The method involves the assumption that tagged fish mix with untagged fish in a uniform distribution, that no recruitment occurs during the fishing period, and that mortality or removal from capture will be only that associated with the fishery.

In the shad runs, a uniform distribution of tagged fish can only be assumed if tagging is carried on continuously and in proportion to the size of the run during the entire period. While it may appear that tagged and untagged fish must run the nets in passage both up and

down the river so the take would be proportional, this would be true only if the fishing effort were constant and there were no net lift period. Fish on the main spawning beds are out of the fishery and only a small part of the escapement after spawning is ever taken in the nets. Without uniform tagging effort the passage of tagged fish during the most intensive fishing period would result in a greater recovery of tags and an apparently decreased population total. If tagged fish passed the nets during a period of lower fishing pressure, the reduced recovery of tags would result in an increased population figure when applied to the season total. The method described in this paper also has inherent error, as previously stated, and results in a comparative index of proportionate abundance rather than an actual figure for the population.

Flow data for the Hudson River near Troy (just below its confluence with the Mohawk) were compiled from U. S. Geological Survey data for 1935 through 1947 and are presented in Table 5. In the columns for the average flow for each month parenthetical figures from 1 to 13 are given to indicate the relative rank of the various years involved with respect to the flow for that month. These ratings have been used to calculate the ratings which appear in parentheses in the year column. The figures for March, April, and May represent a comparison for the months when the flow might affect deposition and hatching of eggs, while those for the 7-month period represent the flow through the entire time young shad might be expected to be in the stream. An additional column has been included to show for each year the ratio between the level of abundance that year (representing a year of egg deposition) and that 5 years later when the majority of this year class returned to the river to spawn. Comparison shows no apparent association with either a high or low rate of flow. This would not be the case if pollution were a significant factor in shad abundance in this stream.

Chemical investigations were made on the Hudson River in 1934, 1936, 1949, and 1951 (New York State Conservation Department, 1935, 1937; New York State Health Department, 1949, 1951). Stations for the earlier years, located as closely as possible to those used in 1951, have been selected for comparison and the data are presented in Table 6.

While, on the basis of these figures alone, it might be inferred that the oxygen content ran consistently lower in 1951 than in the other reported years, the data are on a considerably different base. In 1951 each station was sampled 16 times at three different depths. None of the other surveys sampled the river more than twice at the

Table 5. Flow of the Hudson River Below Its Confluence with the Mohawk River (1935-47)* in Relation to Trends in Shad Abundance

Year	Relative rank by period§		Average flow in cubic feet per second†								Relative abundance of shad in fifth year following‡	
	1	2	March	April	May	June	July	August	September	Average	Year	Ratio
1935	9	4	22,333(5)	18,095(11)	16,587(7)	8,154(9)	21,519(1)	7,499(2)	6,240(6)	14,346(6)	1940	1.94
1936	4	12	54,180(1)	31,100(4)	13,326(10)	4,894(12)	3,656(12)	3,514(12)	4,286(11)	16,422(4)	1941	1.22
1937	7	6	10,669(11)	29,200(6)	24,706(4)	10,872(8)	7,744(5)	7,132(4)	6,261(5)	13,798(7)	1942	1.06
1938	12	10	21,870(7)	17,341(12)	9,112(12)	4,896(11)	5,935(9)	6,157(6)	20,665(1)	12,282(11)	1943	1.43
1939	5	11	22,100(6)	36,970(2)	14,015(9)	6,413(10)	4,331(11)	3,953(11)	3,726(13)	13,073(9)	1944	0.93
1940	6	5	8,203(13)	50,710(1)	22,796(5)	12,235(6)	9,100(4)	4,987(9)	6,322(4)	16,336(5)	1945	1.20
1941	13	13	10,112(12)	22,470(9)	4,484(13)	3,130(13)	2,608(13)	2,209(13)	3,727(12)	6,962(13)	1946	0.85
1942	11	8	21,323(8)	22,594(8)	10,479(11)	12,486(5)	5,415(10)	5,096(8)	7,782(3)	12,167(12)	1947	0.48
1943	1	2	31,640(3)	23,960(7)	39,200(1)	13,995(4)	7,182(6)	8,854(1)	5,615(8)	18,635(3)	1948	0.56
1944	8	9	19,759(10)	30,890(5)	14,947(8)	11,478(7)	6,041(7)	4,325(10)	5,684(7)	13,303(8)	1949	0.56
1945	3	1	41,130(2)	20,785(10)	29,200(3)	14,051(3)	11,055(3)	7,148(3)	10,699(2)	19,153(2)	1950	0.19
1946	10	7	30,700(4)	9,770(13)	17,582(6)	14,418(2)	6,003(8)	5,287(7)	4,576(10)	12,619(10)	1951	0.55
1947	2	3	20,462(9)	33,560(3)	34,260(2)	25,520(1)	12,028(2)	6,882(5)	4,790(9)	19,643(1)	1952	1.10
Average.....			24,191	26,726	19,284	10,964	7,894	5,619	6,951	14,518	XXX	XXX

* Compiled from records of U. S. Geological Survey.

§ Period 1 constitutes the months of March, April, and May; period 2, the months of March to September inclusive. The values represent the relative rank of the sums of the corresponding values for the individual months included, the highest flow being given a rank of 1.

† Figures in parentheses represent the relative rank of each year for the respective months.

‡ Figures under this heading represent, for each year of flow data, a comparison of the shad abundance indices (from Table 1) for that year and the fifth year following, the ratio being based on the first year's index as unity in each case.

TABLE 6. RANGE OF OXYGEN CONCENTRATIONS RECORDED IN THE HUDSON RIVER AT VARIOUS STATIONS FROM TROY TO PIERMONT

Station number	Station location *	Range of oxygen concentration §			
		1934	1936	1949	1951
15	Troy Locks	6.2–6.8	.....	4.1–4.4	4.2–10.4
14	Menands Bridge	5.9–8.0	.....	3.0–3.1	4.0–10.2
13	Van Wies Point	2.2–4.0	.....	0.5–0.6	1.2– 8.2
12	Stuyvesant	3.8–4.8	.....	2.3–2.4	2.0– 8.4
11	Four Mile Point	3.0–5.6	.....	6.0–6.0	2.6– 8.8
10	Catskill	.....	4.1–5.3	5.8–6.0	3.4– 8.4
9	West Camp	.....	5.0–8.6	5.9–6.2	3.6– 8.8
8	Barrytown	.....	4.4–6.4	6.2–6.5	3.6– 9.4
7	Cove Point	.....	4.6–7.2	5.8–7.2	4.2– 8.0
6	Hyde Park	.....	5.0–5.1	5.4–5.6	3.8– 8.0
5	Milton	.....	4.8–5.1	5.0–5.2	3.2– 7.8
4	Chelsea	.....	5.5–7.4	5.0–5.8	3.8– 8.0
3	Storm King	.....	4.0–5.4	5.4–5.8	4.4– 7.8
2	West Point	.....	4.9–5.2	5.4–5.4	4.4– 7.8
1	Bear Mountain	.....	4.3–4.9	4.8–5.0	4.4– 7.4
0	Stony Point	.....	4.9–5.4	.....	4.0– 7.4
00	Piermont	.....	4.0–6.0	.....	3.6– 8.4

* Station locations for 1934, 1936, and 1949 are those situated nearest to those used in 1951.
§ Expressed in parts per million.

same location. It is quite possible that more extensive sampling in the other years would have shown much lower oxygen concentrations to have been present. In the 1951 study no samples were taken closer than 5 feet from the surface and, therefore, there is no true surface sample.

In the young shad survey made in the same year, out of 171 surface samples taken in the area expected to contain shad, only 15 at four of the 13 stations showed an oxygen content less than 5.0 p.p.m. Three samples from two stations were found to have an oxygen content below 4.0 p.p.m. and at one of these young shad were collected. In the 12 samples with oxygen between 4.0 and 4.99 p.p.m., shad were taken on five occasions. Six of the 15 samples having oxygen concentrations under 5.0 p.p.m. occurred at the uppermost station where shad might possibly be expected to be present. On the occasions when the oxygen content was below 5.0 p.p.m. at this station shad were taken once, compared with only two collections on the eight occasions when the oxygen was over 5.0 p.p.m. In consideration of these data there is no clear indication that an oxygen content as low as 4.0 p.p.m. had any significantly detrimental effect upon young shad.

Ellis *et al.* (1947) have reported that many shad became help-

lessly incoordinate and died before the dissolved oxygen was reduced to 4.0 p.p.m., and that a few died even before it had been reduced to 5.0 p.p.m. On the basis of this work it has generally been assumed that shad require an oxygen concentration above 5.0 p.p.m. That this is not the case in all natural waters is evident in these results from the Hudson River, where some shad were collected in apparently normal condition at an oxygen concentration below 4.0 p.p.m. and on at least five occasions when the oxygen was 4.0 p.p.m. or between that and 5.0 p.p.m. Talbot (undated) has maintained shad experimentally for some time at oxygen levels well below 4.0 p.p.m. with no apparent deleterious effects.

CONCLUSIONS

Calculations and comparison of derived figures to indicate the proportionate abundance of shad in the Hudson River during the period from 1924 to 1953 show no significant relationship to any factor other than net lift period. The rise and decline of the shad fishery appears to be associated with the net lift, increasing steadily with a 60-hour lift period and showing a rapid decline when this was reduced to 36 hours or less. Because increased fishing effort resulted in decreased take it becomes clear that overfishing in the years from 1941 to 1951 was responsible for the decline in the shad fishery which first became evident in 1946.

Nothing in this picture can be used to show that pollution had any different effect during the period of increase in this fishery than during the period of its decline.

There is no indication that a minimum stream standard of 4.0 p.p.m. of oxygen will have any serious detrimental effect on shad, or in any way handicap the recovery of the fishery. In fact young shad collections have supported a slightly lower value. It must be realized that such a figure represents an absolute minimum during adverse stream conditions and is not an average around which the oxygen content may fluctuate. It is clear, then, that the oxygen content will be well above the standard figure nearly all the time and should produce a marked improvement in the condition of the Hudson River. There is no reason on the basis of the evidence given here to assume that shad require preferential treatment over the other warm-water fishes and the "standard" of 4.0 p.p.m. of oxygen may be assumed to be adequate.

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SURVIVAL AND ESTABLISHMENT OF WATERFOWL RELEASED AS DUCKLINGS[1]

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ABSTRACT

A study involving the survival to flight age of liberated ducklings of six species and their subsequent return as breeders was begun in 1952. Survival of three strains of mallards was reported in a previous paper as about 61 per cent, while for the pintails, redheads, canvasbacks, blue-winged teal, and shovellers reported here the average survival appeared to be about 44 per cent. However, the first-year band returns were greater for the latter species than for the mallards. Also, observations during the spring of 1953 indicated a greater degree of return to the site of release for them than for the mallards. This was especially true considering the numbers calculated to have been available to return. There was some evidence of a greater return of females than males to release sites.

Although there have been studies of certain phases of duckling liberation programs (Lincoln, 1934; Errington and Albert, 1936; Benson, 1939; Williams and Kalmbach, 1943; and Brakhage, 1953) and evaluations of mortality and rate of homing (Bellrose and Chase, 1950; Sowls, 1951; and Hochbaum, 1952), there seemed to be certain deficiencies in the findings or evaluations as applied to the somewhat different program in New York State. Because of the paucity of detailed information concerning the survival and establishment of liberated ducklings in new surroundings, this study was planned to follow the birds long enough and intensively enough to provide more definite data. It was hoped to collect information sufficient to guide further releases of various species of waterfowl in New York State, especially pintail and redhead, and to form some basis for their management.

During the summer of 1952, a total of 963 ducklings of six species was released on various marsh areas throughout the State. The survival to flying age of the three strains of mallards used, as well as the methods and the objectives of the study, have been reported (Foley, 1954). The present paper is an additional report giving the survival to flight age of the other species liberated, along with, for all species, the relative degree to which they were taken by hunting and evidence of their establishment as breeders.

PROCEDURE

The ducklings were obtained, reared, marked, released, and fol-

[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project W-39-R.

lowed during the summer of 1952 as described earlier by the writer *(op. cit.)*. Those other than mallards totaled 162, and comprised 72 pintails, 50 redheads, 20 canvasbacks, 10 blue-winged teal, and 10 shovellers. These species were released mostly on the better quality marshes of the Lake Plains region, the diving ducks chiefly on the larger natural marshes. They were followed by the same fieldmen who studied the three strains of mallards. Besides Fish and Wildlife Service bands, all but the blue-winged teal were banded with colored plastic rings for help in identification. None were tagged with plastic neck markers as were certain of the mallard groups.

For purposes of this study band recoveries, reported by the Fish and Wildlife Service through May 15, 1953 were tabulated. Primarily, they represent returns for the first fall and winter after banding, most of which were the result of hunting.

Fieldwork to determine the number of liberated ducks that returned to the study marshes in the spring of 1953 was carried on in conjunction with an investigation of trends in the productivity of native waterfowl. All marshes were covered at least three times, and some more often, from late April to early August. Special effort was made to observe identifying color markings.

FINDINGS

Compared with that for the mallards, the observed survival to flight age for the various other species was apparently lower (Table 1) under the conditions of study in the summer of 1952. A severe drought was felt most keenly during July and August in the Lake Plains counties where most of these ducklings had been released. It was shown in the report concerning the three strains of mallards that the lowest duckling survival was noted in this region which had the least rainfall and, therefore, the greatest reduction in water levels. We must assume that there was a similar effect upon the other species. Thus, it would appear that the survival of these species would ordinarily have been somewhat higher than that observed, and in any case probably not too different from the average for the mallards.

A check on the subsequent survival of all the ducklings released, as well as an index to the comparative amount of hunting provided by the different species, was shown by the first-year band returns received. These are also given in Table 1. On the basis of total numbers banded, it would seem that the mallards provided only half as much sport proportionately as did the other species. It may be noted, too, that the rate of return for them was only about half that which has

Table 1. Degree of Survival, of Recovery by Hunting, and of Return to Release Site for Ducklings Released Experimentally in 1952

Species or strain	Number released*	Number considered to reach flying age§	First-year band recovery†			Calculated number surviving after one open season‡	Degree of return to release site the next spring	
			Number	Per cent	Per cent of those observed to fly		Number observed°	Per cent of calculated survivors
Mallard								
New York	336	186	14	4.2	7.5	158	8	5.1
N. Y. x Canadian	221	149	18	8.1	12.1	113	7	6.2
Canadian	244	156	14	5.7	9.0	128	8	6.3
Sub-total	801	491	46	5.7	9.4	399	23	5.8
Other species								
Pintail	72	30	8	11.1	26.7	14	11	78.6
Redhead	50	23	6	12.0	26.1	11	6	54.5
Canvasback	20	4	1	5.0	25.0	2	0	....
Blue-winged teal	10	10	0	....	....	10	0	....
Shoveller	10	4	2	20.0	50.0	0	0	....
Sub-total	162	71	17	10.5	23.9	37	17	45.9
Total	963	562	63	6.5	11.2	436	40	9.2

* Number of mallards liberated as shown here differs from that given previously (Foley, 1954) when 254 Canadians were listed instead of the correct number of 244.

§ Based on following carefully a large proportion of each species and applying the findings to the total for each.

† Returns received through May 15, 1953.

‡ Calculated on the basis of those observed to reach flying age and on the assumption that only half the banded birds taken were reported.

° Most of these ducks were definitely identified as returning birds by color bands, but a few were observed as banded with Fish

been recorded for wild-trapped mallards and black ducks banded as older birds. The average first-year return of 5.7 per cent for mallards was also lower than that of 7.7 per cent recorded earlier in this State by Benson (unpublished) for similar 5-week-old ducklings. The chief reason for this may have been that in the current study the birds were liberated on small, refuge-like marshes where shooting was prohibited. Most of the other species, as well as the mallards studied by Benson, were released on large areas close to (or, in Benson's case, supporting) fairly heavy hunting pressure. Brakhage (1953) indicated, based on work at Delta, Manitoba, a greater first-year return for artificially propagated ducks of three species from the marsh where they were released than for those wild-trapped as juveniles. It is, therefore, believed that the mallards in this study actually survived through the hunting season to a greater degree than the various other species, though for this year's work these differences probably reflect more the type of area upon which the releases were made than any factor inherent in the birds.

The remaining portion of Table 1 is based upon certain assumptions and calculations. These are admittedly indefinite in certain respects, although they are within the limits found by other workers. The presentation does indicate what the degree of survival and establishment reasonably may have been.

First, the assumption was made that only half of the banded birds taken were reported. This is about what other workers have found (Bellrose and Chase, 1950) and it agrees with New York banding records which show that reward bands were reported 2.3 times as frequently as regular bands. Using this factor the numbers of the various species and strains calculated as still surviving after one gunning season are shown. No additional corrections have been made for mortality other than that from hunting. Considerable numbers of mallards of all strains were thus believed to have been available to return for nesting the following spring, while fewer, both actually and comparatively, of the other species were believed to have run the gauntlet successfully. The percentages of those considered to have reached flying age were 81.3 for all the mallards and 47.2 for the pintails and redheads. However, the 1953 field work revealed that over 54 per cent of the redheads and over 78 per cent of the pintails calculated as able to return were seen at the release sites, while the mallard strains averaged only about 6 per cent.

Hochbaum (1952) referring to work with nest-trapped females in the Delta Marshes, reported that 27 per cent, of a total of 152 of

various species, returned to nest in the same meadow the following year. Also, with respect to the same locality, Sowls (1951) found that 15 (or about 13 per cent) of 115 artificially propagated pintail females returned the following spring to the marsh where they had been released. Using Sowls' records and a method of estimating survival similar to that outlined in Table 1, Brakhage (1953) calculated that 13 of these birds should have returned. That 15 actually did return indicates a very high homing rate for the survivors. While this is a higher homing rate than the 78 per cent found for the pintails in New York, it is probably reasonable since Sowls' birds were released on a marsh supporting a native pintail breeding population and from which the eggs involved had originally been gathered. Furthermore, because the stock used in New York included both sexes, it may be that the rate of return for the females alone more nearly approached that recorded by Sowls.

The migration pattern of the ducklings during the first fall, as plotted from band recoveries, fell well within the species flight routes already defined from records of wild-trapped birds. Proportionately more of the pintails and redheads were found to wander erratically than even the Canadian mallards, but probably the numbers were too small to be significant. The most important point would seem to be that most of the mallard recoveries were obtained within 50 miles of

Table 2. Percentage of Total Band Recoveries* from Points Within 50 Miles and from Points Over 50 Miles from the Release Site for Ducklings Liberated in 1952

Species or strain	Number released	Number of recoveries	Per cent taken within 50 miles of release site	Per cent taken over 50 miles from release site
		Mallard		
New York	336	14	71	29
N. Y. x Canadian	221	18	61	39
Canadian	244§	14	64	36
		Other species		
Pintail	72	8	25	75
Redhead	50	6	33	67
Canvasback	20	1	100	0
Blue-winged teal	10	0	...	..
Shoveller	10	2	100	0

* Received through May 15, 1953.
§ See first footnote under Table 1.

the release site, while most of the pintail and redhead recoveries were made at greater distances (Table 2). At present, insufficient numbers of wild-trapped juveniles of these latter species have been banded in this State to make comparisons with artificially propagated birds as did Brakhage (1953) for Delta, Manitoba.

Field work during 1953 showed that each of the mallard strains, as well as the pintails and redheads, was represented by birds which returned to the site of liberation or its vicinity. The proportions of the areas used to which birds returned the following spring are shown in Table 3. The observations on which return was judged were made sufficiently late in the spring to rule out very largely the possibility of transients still being present.

For the New York strain of mallard, ducks classed definitely or very probably as returning birds were recorded at 6 of the 20 release sites covered intensively by project fieldmen. For both the crosses and

Table 3. Proportion of Release Sites to Which Stock Released Experimentally in 1952 Returned in the Spring of 1953

Species or strain	Number of release sites *		Sites to which stock returned in 1953	
	Used 1952	Checked 1953	Number	Per cent
Mallard				
New York	28	20	6	30.0
N. Y. x Canadian	19	16	4	25.0
Canadian	21	16	4	25.0
Total	68	52	14	26.9
Other species				
Pintail	6	5	3	60.0
Redhead	3	3	1	33.3
Canvasback	2	2	0	....
Blue-winged teal	1	1	0	....
Shoveller	1	1	0	....
Total	13	12	4	33.3

* Because each experimental lot of ducklings was considered as a separate unit and because, in many cases, the same release site was used for more than one such lot, the number of release sites listed is greater than the number of actual marshes involved. For mallards, a total of 44 marshes was used in 1952 and 35 were checked in 1953. For the other species, the corresponding figures were 7 and 6, respectively.

the Canadians the figure was 4 out of 16 sites. There was, therefore, no significant difference noted in the degree of homing instinct between the three mallard strains. For the pintails it was observed that they returned to 3 of 5 sites studied, while redheads were observed to return to 1 of 3 sites. This would seem to indicate a somewhat greater rate of homing for these species than for the mallards, although the data are meager.

There is some evidence to indicate that there were significantly greater proportions of females than males in the release groups from which individuals returned to or near the release site the following spring. Also, of all returning birds observed, 53.2 per cent were females and 46.8 per cent were males, although these data include "probables". Actually, the percentage of females probably was greater.

DISCUSSION

There are many possible reasons for the apparent discrepancy between the degree of return to the site of release observed for mallards and that for the other species. There was more consistent coverage of the areas where the other species were released, and these areas were of larger size and better quality with a possibly greater attraction for waterfowl. There is also the possibility that the mallards, in a region where they were already fairly common, had a greater tendency to disperse to other, non-observed areas upon returning. It is likely, too, that many returning mallards from these experimental groups went unnoticed among other, unbanded, mallards. Probably each of these reasons, and perhaps others, operated to some extent to cause the wide difference in the figures recorded, but it is believed, nevertheless, that the data presented generally indicate the true situation.

Although a somewhat different behavior was indicated by the various data collected for the mallard strains compared with those for the other species, the reasons given would seem to explain it. The mallards apparently exhibited greater initial survival than the others up to the age of flying, as well as greater survival through the hunting season. If, however, the numbers observed to return to the release site the following spring were true indications of establishment, then the conclusion must be that pintails and redheads will be easier to build up as breeders in this State by stocking than the mallard has been. Whether the mallard has been more successful as a result of the duckling liberations than as a result of the release of adult breeders is a moot question. At the same time, the reasons given as to why the results with ducklings might not be actually so encouraging as they

appear to be probably explain, to a large degree, why we should be cautious in predicting the outcome of such stocking.

CONCLUSIONS

The most important conclusion to be reached from these studies concerning the survival and establishment of ducklings of various species released at 5 weeks of age is that, in addition to mallards, which already breed on many water areas of the State, other species such as the pintail and redhead may also be successfully introduced. There are a number of unanswered questions concerning the evaluation of the observed results, yet from any standpoint the latter species did very well indeed.

There was also some evidence that in the release groups from which birds returned to or near the release site, there were greater proportions of females than males.

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A SURVIVAL EXPERIMENT AND AN EXAMPLE OF SELECTIVE SAMPLING OF BROOK TROUT (*SALVELINUS FONTINALIS*) BY ANGLING AND ROTENONE IN AN ADIRONDACK POND[1]

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ABSTRACT

A 4.6-acre Adirondack pond was reclaimed in 1951 and was restocked with four groups of brook trout from wild and domestic sources in 1952 with the intent to observe relative survival. Owing to the inadvertent introduction of gill lice with one group of wild fish, the experiment was prematurely terminated in 1953. Angling in the pond and two subsequent treatments with rotenone produced different ratios in the recovery of the stocked fish and of a group of naturally produced trout, the results of natural spawning in 1951 by adult trout which were missed in the original treatment. The ratio of the recovery for the four groups of stocked fish differed significantly from that expected on the basis of the stocking ratio.

In the summer of 1951 a small Adirondack trout pond, located on the Brandon Preserve near Paul Smiths, New York, was reclaimed with rotenone[2] as a routine management procedure. A survival experiment was incorporated into the restocking program but unforeseen circumstances caused premature termination of the study. Even so, the preliminary data of the experiment, coupled with observations on the use of rotenone, appear worth recording.

Bear Pond is 4.6 acres in area with a maximum depth of 20 feet and a volume of about 70 acre-feet. It is thermally stratified with good oxygen through most of the hypolimnion. Located in a sheltered kettle hole, the pond has a watershed scarcely equal to its area and is

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[1] Mr. and Mrs. Donald P. Ross of Montchanin, Delaware, kindly made the pond available for experimentation and have implemented the work in other ways. The following have assisted with various phases of the field work: Robert H. Kimpton, Jr., of Saranac Inn (N. Y.); Harry Cook, Burnham Campbell, Roy Hungerford, and Albert Cummings of Paul Smiths (N. Y.); Dr. Alfred Eipper, Dr. Saul Saila, Paul Neth, and G. Scott Little of Cornell University. The yearlings in Group 1 were made available through the U. S. Fish and Wildlife Service. Dr. E. C. Raney, Cornell University, checked or made the identification of certain of the Cyprinids. Dr. J. R. Greeley, Dr. C. W. Greene, Dr. W. M. Lawrence, R. G. Zilliox, New York State Conservation Department, and Dr. G. A. Swanson, Cornell University, have commented upon the manuscript.

[2] Emulsifiable rotenone 5 per cent was used in this and subsequent reclamations in a quantity calculated to give a concentration somewhat in excess of 0.5 p.p.m.

fed almost entirely by springs. Unlike most Adirondack waters it has a perpetual and marked plankton bloom and is slightly to strongly alkaline in pH. Bear Pond contained nine native species plus yellow perch *(Perca flavescens)* and golden shiners *(Notemigonus crysoleucas)* which had invaded the pond through connection with the St. Regis River.[3]

The experimental plantings were made in May, 1952, using brook trout from four sources. The intent of the study was to yield information pertaining to relative survival in four groups of trout offering different environmental backgrounds and potential variation in genetics. The groups consisted of:

1. Domestic yearlings from U. S. Fish and Wildlife Service Hatchery, Cortland, New York.
2. Yearlings, first generation wild, removed from a Cornell University farm pond. This group was planted as unfed fry hatched from eggs taken from Cortland stock parents after 1 year in the wild (parent stock planted as fingerlings).
3. Domestic yearlings hatched at Cobbs Creek Fish Hatchery, Forestport, New York, from wild western eggs.
4. Wild brook trout of various ages taken from a nearby stream on the Brandon Preserve.

Groups 1 through 3 were distinctively fin-clipped and averaged 6.2 to 7.6 inches in total length. The wild fish were not marked and varied from 5 to 10 inches in length. Later it was found that gill lice *(Salmonicola edwardsi)* had been inadvertently introduced along with the wild trout and it was decided to rotenone the pond again in the early summer of 1953. The fish recovered during the second reclamation and antecedent angling provided an unusual example of selective sampling. Data relating to survival, while incomplete, also appear worth recording.

The first sample was made by angling in early October, 1952. At this time nearly all of the 51 trout caught were in spawning condition, and the marked groups adequately sampled had increased an average of 2 to 3 inches in length. The condition of the fish was excellent and

[3] The balance of the species consisted of brook trout, white sucker *(Catostomus c. commersoni)*, brown bullhead *(Ameiurus nebulosus)*, redfin shiner *(Notropis cornutus)*, horned dace *(Semotilus atromaculatus)*, northern pearl dace *(Margariscus margarita nachtriebi)*, fine-scaled dace *(Pfrille neogaea)*, northern redbellied dace *(Chrosomus eos)*, black-nosed dace *(Rhinichthys atratulus)*, and pumpkinseed sunfish *(Lepomis gibbosus)*.

only a moderate infestation of the gill lice was noted. Numbers representing the four groups and other pertinent data are presented in Table 1.

Table 1. Angling Sample of October, 1952, from Four Groups of Brook Trout Planted in Bear Pond in May, 1952

Item	Group			
	1	2	3	4
Number planted	100	200	100	150
Number observed	10	24	1	16
Number expected	9	19	9	14

The poor representation of the Group 3 fish is not readily explained by sampling error alone (chi-square=9.36; P=7.82, d.f.=3). At the time, a plausible explanation appeared to be the lack of sexually mature trout in this group, as indicated by trout taken in another pond concurrently stocked from the same hatchery lot. As the angling sample above was largely the result of fishing two concentrations of spawning trout in the pond, non-spawning trout would tend to have been poorly represented.

During the late spring of 1953 there appeared unmarked trout of uncertain origin. These fish differed from the unmarked wild trout stocked in their smaller size (6 to 7 inches), body conformation, coloration, and age. They were small-headed, gracile fish with large pale spots and prominent parr marks, and were in their second season of growth (age I+). The only rational explanation for their presence was that a few of the original trout inhabitants had survived the rotenone treatment and spawned in the fall of 1951. Survival of suckers was also known from the presence of young taken in minnow traps in the summer of 1952.

The infestation with gill lice in these small fish was very light, usually with none to one or two lice present. By contrast, the larger 9- to 12-inch fish of the experimental plantings had become heavily parasitized by the late spring of 1953. Gills and fins sometimes carried a dozen or more lice, and the gill filaments were commonly severely eroded and discolored or pale. Some specimens were in poor condition.

On June 12, just prior to the second reclamation, attempts were made to catch by angling and release a group of fish bearing a temporary mark (tip of the dorsal lobe of caudal fin removed by fin

clipping), so that population estimates could be made from the rotenone kill. Forty trout were so marked. Of 19 personally seen by the writer, 16 were the small, naturally spawned trout hereafter designated as Group X, while three trout belonged to Group 2. Most of the other trout given a temporary clip were likewise reported to be Group X fish. During the evening rise it was evident that a substantial number of trout were present in the pond, and the angling sample suggested most of them to be Group X.

The rotenone application on June 13, 1953, produced an unexpected representation in the trout collected. Fifteen gallons of rotenone stored from the previous year were applied using surface and deep pumping techniques. A good crop of 6- to 8-inch suckers first succumbed, presumably the result of spawning in 1952. One large sucker was recovered and at least one other seen. Brook trout was the only other species of fish observed. Except for the 1953 hatch of fingerlings (the 27 collected averaged 2.5 inches), the remaining trout were slow to appear. Only 34 were recovered despite the activities of crews in three canoes with this mission (included are nine trout picked up on June 14). Only one of these trout bore a temporary mark. Groups 1 to 4 totaled 26 fish and Group X, 8.

This was a reversal of what might reasonably have been expected on the basis of the angling sample taken on the day previous. The poor recovery of trout was discouraging. The reversal in ratio was disturbing although it was easy to entertain a plausible "explanation" in possible differences in feeding habits of the two sizes of trout, hence selection by angling of the smaller fish at this particular time.

Three weeks later trout were again reported rising in the pond, necessitating another treatment with rotenone.

An application of 18 gallons of recently purchased material was made on July 9, 1953. No fish other than brook trout appeared. Of the 26 trout recovered, 5 belonged to Groups 1 to 4, and 21 to Group X.[1] Thus, Group X was accounted for, though the differences in sampling were perplexing. No additional temporary marked trout were noted although it is uncertain whether or not this mark would

[1] Combining the two rotenone samples, 60 trout were recovered from a population which probably numbered several hundred, excluding young of the year. There was little likelihood of migration from the pond as the outlet was screened except while icebound in the winter of 1952-53. Only 63 of the 550 trout stocked were removed by angling. Periodic inspection of the pond for a week or so after each application disclosed only a few additional dead fish. Apparently most of the trout died without showing distress at the surface and the trout recovered were a small part of the trout population present.

still have been recognizable. A summary of the three 1953 samples discussed above is given in terms of approximate ratios (Table 2).

Although the number of individuals involved was small, the differences encountered can scarcely be attributed to sampling error. An attempt to explain the observed variations in sampling must of necessity be largely subjective. However, the following rationalization appears plausible. The ratio in the angling Sample A was due to selectivity as previously suggested, although not necessarily selection

Table 2. Approximate Ratio of Recovery in Three Samples from Two Groups of Brook Trout, Bear Pond, 1953

Sample	Groups 1 to 4	Group X
A—angling June 12, 1953	1	6
B—rotenone June 13-14, 1953	3	1
C—rotenone July 9, 1953	1	4

ascribed to feeding. The rotenone used in obtaining Sample B was of reduced toxicity (its consistency and color was quite different from fresh material, but actual rotenone content was not determined) and it was lethal largely to trout in which respiration was impaired, namely Groups 1 to 4 that were heavily infested with gill lice. Suckers were caught in warmer surface water around the shoreline where the effective toxicity was greater. Sample C eliminated (it is hoped) the surviving trout, most of which were Group X. This group had survived the previous treatment due to lesser damage to the respiratory tissues.

The survival experiment can be summarily disposed of by data giving the total observed frequency of all fish taken by angling in 1952 and the early spring of 1953, supplemented by those killed by rotenone (Table 3). Only fish inspected by the writer are included to reduce the possibility of overlooking or confusing marks.

Table 3. Observed and Expected Numbers of Brook Trout in Total Sample from Four Groups Planted in Bear Pond in May, 1952

Item	Group			
	1	2	3	4
Number observed	14	45	6	33
Number expected	18	36	18	27

As the observed ratio still differed significantly from the number expected on the basis of the stocking ratio (chi-square = 12.47; P = 11.31, d.f. = 3) the conclusion follows that these four groups of brook trout exhibited a differential survival during the 1-year period. The major deviation was still in Group 3, domestic yearlings from wild eggs. There appears no ready explanation for this. At the hatchery it was noted that these fish tired very readily when confined in a seine and during marking. This was thought to have been due to relatively low oxygen values in the crowded hatchery pond, but it might have been caused by something less obvious, anemia, for example. Experimentally it would have been preferable to have had Groups 1 and 3 reared at the same hatchery. Other than this, all procedures relating to marking, transportation and planting were similar. As noted elsewhere, a planting of other individuals from this same hatchery lot was made in another pond and the survival here appears to have been good.

It might be pointed out that the two hatchery groups (1 and 3) were alike in being below the expected number in total recoveries, while the two "wild" groups (2 and 4) were above the expected. This readily could have been due to fortuitous circumstances, but the data, although only suggestive, indicate a higher survival of the "wild" groups of brook trout over the 1-year period.

GENERAL NOTES

THE RACCOON AS A WILDLIFE RESERVOIR OF *LEPTOSPIRA CANICOLA*

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During routine autopsies at the Wildlife Research Laboratory many raccoons exhibited typical distemper pathologies, enteritis, hepatitis, and occasionally some icterus. Other raccoons which were sick though still alive when they arrived at the laboratory exhibited clinical symptoms of apathy, anorexia, lassitude, depression, definite muscular tremors, dyspnea, clonic-tonic convulsions, deep coma, and finally death. Also, reports were received of raccoons which seemed to lose their fear of man, becoming quite docile and even wandering into yards to play with children.

Brain tissue was sent to the Division of Laboratories and Research, New York State Department of Health, for examination for rabies. Negri bodies were not found nor did animal inoculation produce rabies. It was decided to test for leptospirosis. Therefore, a blood sample was taken from the heart of a sick raccoon and sent to the Division of Laboratories and Research for an agglutination test for this disease. Titers of 1:1000 were obtained with *Leptospira canicola* but no significant agglutination resulted with *L. icterohaemorrhagiae, L. pomona,* or with *Leptospira* species of bovine origin isolated in New York.

Since this first raccoon was tested, blood samples taken from three other sick raccoons have given positive agglutinations for *L. canicola.*

The presence of *L. canicola* in a wildlife population (i.e., in raccoons) is of particular importance and significance from the veterinary and public health standpoint since it is the etiological agent of canine and, in some cases, human leptospirosis.

The writer wishes to express his sincere appreciation for the excellent cooperation received from the Division of Laboratories and Research, New York State Department of Health, and particularly to Dr. Victor Tompkins and Dr. Donald Dean of that Department.

Errata

In the paper "Studies on survival of three strains of mallard ducklings in New York State" by Donald Foley (New York Fish and Game Jour. 1(1):75-83) the total number of ducklings released was given incorrectly. In the abstract (line 2) and on page 76 (line 8) and page 77 (line 16) as well as in Table 1, the figure 811 should read 801. On page 77 (line 4) the figure 815 should read 805. Also on page 77 (line 17) as well as in Table 1, the figure 254 should read 244. Fortunately, the figures in which these errors occurred are apart from those from which the comparative data reported were derived.

INDEX FOR VOLUME I

Algae
control of, 110
effect of ducks on, 110
Angling, as a means of sampling trout populations, 214

Band recovery, waterfowl, 208
Barbehenn, Kile. The effects of ducks on the development of filamentous algae in farm fishponds, 110-115
Bass, smallmouth
age at maturity, 20
effect of fishing, 26
growth, 12
longevity, 21
migration, 6
of Lake Ontario-St. Lawrence River, 1
oxygen requirements, 84, 93
reproduction, 22
sex ratio, 18
tagging, 2
Beaver
age criteria, 27
growth, 37
longevity, 28
pelt size and age, 41
period of birth, 42
population composition, 41
skull characteristics, 34
tooth replacement, 34
X-ray examination, 29
Brown, Charles P. Distribution of the Hungarian partridge in New York, 119-129
Burdick, G. E. An analysis of the factors, including pollution, having possible influence on the abundance of shad in the Hudson River, 188-205
Burdick, G. E., *et al.* Lethal oxygen concentrations for trout and smallmouth bass, 84-97

Cook, Arthur H. and Edward R. Maunton. A study of criteria for estimating the age of beavers, 27-46

Dean, Howard J., see Burdick, G. E., 84
Deer
population composition, 103
retarded antler growth, 106
Deer, hunter kill
as representative of wild population, 102, 106
effect of range accessibility, 100, 105
hunter selectivity, 100
wariness as an influence on, 98
Disease
leptospirosis, 220
Leucocytozoon, 80
Domestic fowl, protein requirements, 172
Duck, black, food, 171
Duck, blue-winged teal
recovery by hunting, 208
return to release site, 208
survival of game farm stock, 207
Duck, canvasback
recovery by hunting, 208
return to release site, 208
survival of game farm stock, 207
Duck, mallard
effect of various diets on breeding, 178
effect on algae, 110
nutrition, 171
recovery by hunting, 208
return to release site, 208
survival of game farm stock, 75, 206
Duck, pintail
recovery by hunting, 208
return to release site, 208
survival of game farm stock, 207
Duck, redhead
recovery by hunting, 208
return to release site, 208
survival of game farm stock, 207
Duck, shoveller
recovery by hunting, 208
return to release site, 208
survival of game farm stock, 207
Ducks
effect on algae, 110
food habits, 172
also, see various species, waterfowl

Electric fields
nature of field in soil, 144
nature of field in water, 138
reaction of fish to, 47, 130
relation to fish shockers, 130
water and soil resistivity, 164

Farm fish ponds, effect of ducks on algae in, 110
Fish, reaction to electric fields, 47, 130
Fish population of an Adirondack pond, 215
Fish shockers
alternate-polarity-electrode system, 160
back-pack, 65
electrical requirements, 131
grounded system, 137
long parallel-electrode system, 162
relation to electric fields, 130
two-electrode system, 149
Foley, Donald. Studies on survival of three strains of mallard ducklings in New York State, 75-83 (see also p. 220)
Survival and establishment of waterfowl released as ducklings, 206-213
Food habits
duck, black, 171
ducks, general, 172
Freeman, Roderic, see Haskell, David C., 65

Geduldig, Donald, see Haskell, David C., 47
Growing season (map), 126

Harris, Earl J., see Burdick, G. E., 84
Haskell, David C. Electrical fields as applied to the operation of electric fish shockers, 130-170
Haskell, David C., *et al.* Two back-pack fish shockers, 65-74
Reactions and motion of fish in a direct current electric field, 47-64
Holm, Earl R. and M. L. Scott. Studies on the nutrition of wild waterfowl, 171-187
Hudson River
abundance of shad in, 188
oxygen content, 201
volume of flow, 201
Hunting
relation to waterfowl survival, 208
also, see deer

Leptospira canicola, in raccoon, 220
Lice, gill, relation to trout survival, 215
Lime, requirement map, 124
Lipschuetz, Morris, see Burdick, G. E., 84

MacDougal, John, see Haskell, David C., 47, 65
Maguire, H. F. and C. W. Severinghaus. Wariness as an influence on age composition of white-tailed deer killed by hunters, 98-109
Maunton, Edward R., see Cook, Arthur H., 27

Oxygen
concentrations lethal to trout and bass, 84
requirements for shad, 188, 203

Partridge, Hungarian
distribution in New York, 119
early stocking, 119
factors influencing survival, 126
Pasko, Donald G., see Stone, Udell B., 1
Pollution, relation to shad abundance, 188, 198
Population composition
beaver, 41
deer, 103
Precipitation, mean annual (map), 125

Raccoon, parasitism, 220
Reilly, James R. The raccoon as a wildlife reservoir of *Leptospira canicola,* 220
Reproduction
bass, smallmouth, 18
mallard, effect of various diets, 178
Roecker, Robert M., see Stone, Udell B., 1
Rotenone, as means of sampling trout populations, 214

Schierbaum, Donald. A successful diving duck trap, 116-117
Scott, M. L., see Holm, Earl R., 171
Severinghaus, C. W., see Maguire, H. F., 98
Sex ratio, bass, smallmouth, 18
Shad
effect of fishing intensity on abundance, 200
influences on abundance in the Hudson River, 188
oxygen requirements, 188, 203
spawning grounds, 198
take by netting, 191
trends in abundance, 190
Stocking
Hungarian partridge, 119
waterfowl, 75, 206

Stone, Udell B., *et al.* A study of Lake Ontario-St. Lawrence River smallmouth bass, 1-26

Tag recovery, bass, 3
Talmage, Everett, see Schierbaum, Donald, 116
Techniques
calculation of shad abundance, 189
collection of fish by electrical means, 47, 65, 130
deer checking station data as representative of the legal kill, 102, 106
determining oxygen requirements of fish, 86
diving duck trap, 116
marking ducks, 76
measuring soil resistivity, 167
measuring water resistivity, 164
sampling trout populations, 214
tagging bass, 3
X-ray of beaver, 29
Trout, brook
oxygen requirements, 84, 89
sampling populations, 214
survival, 214
Trout, brown
electrical resistance, 135
oxygen requirements, 84, 90
reaction to electric fields, 48, 130
Trout, rainbow
oxygen requirements, 84, 92

Water analysis
Rochester tapwater, 88
Rome Fish Hatchery, 88
Waterfowl, nutrition, 171
Water pollution control law, 188
Webster, Dwight A. A survival experiment and an example of selective sampling of brook trout *(Salvelinus fontinalis)* by angling and rotenone in an Adirondack pond, 214-219